

# **SURVEY OF EXISTING AND PROMISING NEW METHODS OF SURFACE PREPARATION**

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## FOREWORD

This research project was performed under **the National Shipbuilding** Research Program. The project, as part of this **program, is a cooperative** cost shared effort between the Maritime Administration and Avondale Shipyards, Inc. The development work was accomplished by Steel Structures Painting Council (SSPC) under subcontract to Avondale Shipyards. The overall objective of the program is improved productivity and, therefore, reduced shipbuilding costs to meet the lower Construction Differential Subsidy rate goals of the Merchant Marine Act of 1970.

This report was prepared by Mr. John D. Keane, Director of Research, Dr. Joseph A. Bruno, Assistant Director of Research and Mr. Ramond E. F. Weaver, Research, Technologist.

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## EXECUTIVE SUMMARY

The U.S. Shipbuilding industry and the U.S. Maritime Administration recognizes that an acute need exists for increasing productivity in U.S. shipbuilding in the interest of national security and the health of the economy. They also recognize that surface preparation plays an increasingly important role in the complex and integrated technology involved in designing, building, and maintaining ships. At the same time it is recognized that this need for improved efficiency, productivity, and competitiveness comes at a time when the conventional methods of ship plate surface preparation, particularly open abrasive blasting, have come into serious question from the standpoint of health and pollution. Although some recent exceptions and deferments have been obtained, restrictions by EPA, CARB, OSHA, labor, and local agencies will add further to the limitations already imposed on alternative cleaning methods.

This study was undertaken to survey existing and promising surface preparation methods and equipment which might answer some of the questions identified in the paragraph above. To accomplish this task the SSPC assembled surface preparation experts from many diverse industries to help organize and direct the project. This report is the final product of the study.

The first part of the report contains a state-of-the-art review of methods presently being used throughout the world. The second part of the study identifies new and sometimes novel approaches to surface preparation for painting. These include:

- Air/Sand/Water Combination
- Hydraulic Sand Injections
- Zinc Shot Blasting
- Carbon Dioxide Pellet Blasting
- High Velocity Ice Particle Blasting
- Laser and Xenon Lamps
- Plasma-Hot Gas

- Ultrasonic Cleaning
- Cavitation
- Bacterial
- Electrolytic Descaling

Of these methods identified within the report, only three warrant further investigation at this the. These are:

- Air/Sand/Water Injection
- Ž Hydraulic Sand Injection
- Ž Zinc Shot Blasting

A project using cavitation is presently being MarAd cofunded with the Federal Highway Department. The Carbon Dioxide Pellet Blasting was originally scheduled for MarAd investigation, but delayed due to a lack of adequate technical development.

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# **SECTION 1**

## **Conclusions**

## 1. Conclusions

### 1.1 Project Results

A survey was made of existing and promising new surface preparation methods, particularly those which may be used at same stage of shipbuilding to supplement or replace open abrasive blast cleaning and which could possibly result in improved productivity. Based upon a broad critical review and inspection of alternative practices in this country and abroad, a description and analysis are given of applicable methods including:

- Equipment employing recycled steel shot and grit.
- wet blast cleaning methods with and without the use of inhibitors and special primers.
- Water blast cleaning.
- New chemical cleaning methods.
- New power tool cleaning devices.

A few of these promising new methods appear to be basically sound but beyond the scope of this investigation. Examples include a means of altering, preventing or removing mill scale at the hot-rolling temperature. Also included is blast cleaning with water-ice, and paint stripping with hot gas.

A number of other innovative ideas have been proposed for surface preparation which require further investigation prior to actual large scale production applications. use would include cleaning with a laser beam or xenon flash lamps, thermal shock cleaning with plasma torch, mill scale and rust removal bacteriologically, cavitation, ultrasonics, cleaning with explosives or fine air-borne abrasives, and the magnetic propulsion method. Basic research may also be done to develop electrolytic methods of scale

removal from exposed surfaces, to find a suitable water-soluble abrasive, or to find other abrasives Which also act as a passivating agent.

Many of the standard methods in common use are constantly being Improved, for example, hull side, hull bottom and deck centrifugal blast cleaners; other portable blast clening equipment such as vacuum recovery units; improved operator adjustable nozzles; portable wheel units; more effective use of water-curtain, steam sand blasting, and other wet blast methods; alternative non-metallic, non-silica blast media; better power tools, such as the flagellating Wheels and more effective support equipment. Sane of these improved methods are already being used on a trial. basis in sane shipyards.

some really new approaches such as citrate chemical cleaning, have been investigated under the National Shipbuilding Research Program. Blasting with carbon dioxide pellets was also considered for evaluation but not funded to a lack of practical application processes and equipment.

Several promising new methods appear to have sufficient advantages to warrant further investigation leading to pilotplant scale demonstrations. These are discussed in the following paragraphs.

#### 1.1.1 Air/Sand/Water

One such method employs a combination of water, sand, and air. By controlling the amount of abrasive through the use of a metering device, the machine provides operator flexibility. It is ideal in spot cleaning of previously painted surfaces damaged by welding, cutting, burnthroughs, impact and abrasion during fabrication assembly. Also in maintenance painting this method permits cleaning of fouling or real of one, two, or all coats of paint . For blast cleaning of steel in shipyards to white or near-White grade, this method offers several possible advantages including:

- Improved Paint peformance by removing sulphates, chlorides, and other water soluble contaminants from pitted or contaminated steel surfaces.

- Reduced pollution and improved safety in the use of sand by reducing appreciable air-borne free silica.

- Reduced cost due to reduced abrasive consumption.

#### 1.1.2 Zinc Shot Blasting

Another approach that appears to warrant further investigation for certain specialized applications is zinc shot blasting, in which a very thin residue of zinc is applied during the original blast cleaning of the steel as it enters the plant. The coat is apparently thick enough to provide galvanic protection during the fabricating operations but sufficiently thin so as not to interfere with cutting and welding, or to require removal before further painting. Further laboratory work and a pilot plant trial are suggested to determine whether or not step step could be used in place of a pre-construction primer in some shipyards to eliminate double blast cleaning and double priming. This process is presently being further developed in Scandinavia in corporation with SSPC.

### 1.2 Recommendations

A full scale demonstration should be arranged to evaluate the air/sand/water injection blast unit in a U.S. shipyard. Marine surface preparation and pointing experts should be invited to witness the capabilities and performance of the equipment for possible adaptation to U.S. shipyard methodology.

With several of the proposed new methods, quality and paintability of surface are the controlling characteristics, and preliminary evaluations initiated as a part of this study should be continued (see Annex C). These include panel test evaluations on surfaces cleaned by: sand/air/water= blast processes; citrate cleaning; centrifugal flagellating wheel, and several low-silica non-metallic blast media. Surfaces have a wide range of histories in rusting prior to blast cleaning as well as surfaces rusted after blast cleaning should also be included in the paintability series.

## **SECTION 2**

# **Project Plan of Action**



## 2. project Plan of Action

### 2.1 Introduction and Background

A ship structure could be considered a composite of a base material for strength a coating for protection (or appearance), and an interface between the two for adhesion. To a considerable extent, it is the nature of this interface that determines the effestiveness of the composite. It is estimated that at least half to tow-thirds of the funds in a paint system for steel are allocated to surface preparation alone. Of the remainder, at least two-thirds goes for paint application, leaving only 10-15% or so for the actual paint material. This allocation will vary but it does illustrate the importance of surface preparation.

In the cleaning of new steel one of the most important requirements is perhaps the removal of mill scale. This scale is formed in the hot-rolling operation. A layer of iron oxide mill sale only a few thousands of an inch thick is formed on the surface at high temperature. Its depth, composition, and tenacity depend upon the tickness of the steel, its subsequent rate of cooling, and the steel. Composition. Figure 2.1 illustrates typical layer composition and cracks in each layer. During storage of steel, this scale tends to flake away in an irregular manner, resulting in a dissimilar surface which includes intact mill scale, cracked and loose mill scale, rust, moisture, dirt, oily residues, salt, sharp edges, and air-borne contamination. For all anti-corrosive services, thorough surfaces preparation is required, particularly with modern coating most of which do not not the recleaned surface thoroughly.

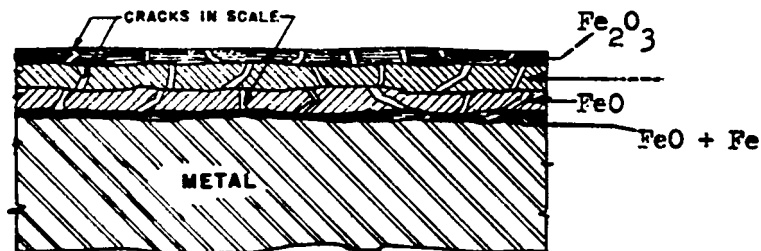


FIGURE 2.1: Mill Scale Layers

Because paint life is dependent primarily upon surface preparation, this aspect of the painting program should receive very thorough consideration. Although all paints will fail eventually, most paint systems fail prematurely because of loss of adhesive or corrosion of the substrate. Therefore, contaminants such as chlorides, salts, sulfates, oil, and grease should be removed, along with rust and mill scale.

The choice of the surface preparation methods, specifications and equipment for a complex structure such as a ship is a difficult one. Some of the factors involved are shown in Table I.

TABLE I  
Factors in Selecting Surface Preparation

- A. Ship Environment
- B. Paint - Tolerance
- C. Profile
- D. Cost
- E. Safety and Pollution
- F. Availability for Maintenance
- G. Equipment Available
- H. Surface Condition - Pitting, etc.

## 2.2 Plan of Action

### 2.2.1 SSPC Advisory Committee

In an effort to overcome some of the shortcomings inherent in many present methods of surface preparation in various stages of shipbuilding and other steel fabrication processes, an SSPC Advisory Committee on New Surface Preparation Methods was organized and held four meetings during the course of this survey.

These meetings were attended by 20 to 40 industry representatives of both users and suppliers of surface preparation equipment and processes. Members of this committee reported on their experiences with new methods and modifications in a wide range of industries. In addition, they devised an analytical classification of possible combinations of equipment, forces, and principles which might conceivably be combined into new approaches to

the surface preparation problem. An outline of the resulting matrix is given in Table II, which shows the force of action required to clean a surface (mechanical, chemical, energy-radiation) versus the type of media or equipment to be used (abrasives and appliances).

TABLE II  
GENERAL SCHEME FOR CLASSIFYING METHODS OF SURFACE PREPARATION

I. CLASSIFICATION ACCORDING TO TYPE OF FORCE APPLIED	II. CLASSIFICATION ACCORDING TO MEDIA OR EQUIPMENT FOR APPLYING FORCE
A. MECHANICAL FORCE pressure; centrifugal; abrasion; direct contact	A. ABRASIVE MEDIA
<b>B. CHEMICAL FORCE</b>	1. <u>Non-Metallic Abrasives</u>
1. Acids a. pickling acids b. phosphate treatment c. naval jelly d. organic acids	a. naturally occurring i. sands ii. flint iii. garnet iv. zircon v. novaculite
2. Alkalis a. detergents b. caustics c. organic chelating complexes	b. by-products i. slags ii. walnut shells iii. corncobs
3. <u>solvents</u>	c. manufactured i. silicon carbides ii. aluminum oxides iii. solid CO <sub>2</sub> iv. air
4. Reducing Agents	2. <u>Metallic Abrasives</u>
C. OTHER FORCES	a. ferrous (grit or shot) i. iron ii. steel iii. stainless steel iv. cut iron wire
1. <u>Thermal Force</u> a. direct heat transfer i. steam ii. flame	b. non-ferrous i. Zinc shot ii. aluminum shot
2. <u>Energy Radiation</u> a. sound i. ultrasonic ii. vibratory b. electromagnetic i. laser ii. microwave iii. high intensity light iv. infrared heat v. induction	B. APPLIANCE OF FORCE Rigid abrasive wheels Flexible abrasive coating materials Hardened needles Bundled wire segment Sharpened or hardend cutters

2.2.2 Shipbuilding and Other Marine Sources. The following U.S. and foreign shipbuilding companies were visited during this Study:

Avondale shipyards, Incorporated  
Camel-Laird Shipbuilding, Limited  
Davies Shipbuilding, Limited  
Dravo Corporation  
General Dynamics (Quincy Shipbuilding Division)  
Odense steel shipyard, Limited

2.2.3 Other Industrial Sources. The companies **listed in the** foreword contribute background information on practices **and procedures** used in this report .

In addition, visits were made to KUE Engineering Limited, Wheelabrator-Frye Incorporated, and Williams Contracting Incorporated.

2.2.4 Literature Survey. A broad range of sources was used, including the specialized library located at SSPC headquarters on the subject of surface preparation. This was supplemented by the libraries of Mellon Institute, Carnegie-Mellon University, Carnegie Institute, and SSPC members. In addition, conventional sources (such as the Library of Congress) were also consulted when related work was needed.

A computerized information retrieval system was also used to scan previous literature. In addition, manual searches of current journals and abstracts were conducted. Survey articles<sup>(29,41,73)</sup> and other more specific articles are summarized in the annotated bibliography (see Annex A).

The Steel Structures Painting Manual, Volume 1, "Good Painting Practice" is currently being revised and updated. Contributions to this Proposed new edition, pertinent to surface preparation, were used in preparation of this report and are referenced after the annotated bibliography<sup>(118-124)</sup> .

2.2.5 SSPC Experimental Work Related to Surface Preparation. SSPC has also done extensive experimental work relating to surface preparation (69, 70, 72, 74, 75, 138). Specific details concerning this work are discussed in Annex C.

## **SECTION 3**

### **Project Results**

### 3. Project Results

#### 3.1 Existing Surface Preparation Methods and Procedures

##### 3.1.1 Conventional Shot and Grit Blasting

3.1.1.1 Centrifugal Blast Cleaning - Since their introduction in 1932, centrifugal (airless) blast cleaning machines have assured an ever increasing percentage of the steel fabrication blast cleaning requirements. Centrifugal blast cleaning is ordinarily associated with the use of metallic shot or grit, with closed cabinets or blast rooms to which the work must be brought and with the re-circulation of the metallic abrasive. The metallic abrasives are used in such a manner as to be exposed to a corrosive environment. (See Annex B for a complete discussion of abrasive blast media). Their initial cost is much higher than that of expendable abrasives, but the metallic abrasives can be re-circulated from 50 to 5,000 times before they disintegrate to the point where they are no longer effective. The undersized material is continually removed and replaced by a selected size of shot or grit.

Costs of centrifugal blasting equipment are often considerably lower than those of open blasting. Equipment is cumbersome, however, and work must be brought to it and passed through on a conveyor or rotary table so that every area can be cleaned.

Shell Limited<sup>(115)</sup> has found a higher production rate with the coarser abrasive in an impeller (wheel) type of machine using shot and grit. They also found no problem with trapped rust and mill scale when shot was used as the abrasive, but did find some folding over of the surface with resultant trapping of rust and mill scale fragments when grit or sand were employed. Most other investigators, however, find that the use of steel grit, sand, or mineral abrasives instead of shot tends to reduce the possibility of driving mill scale or other impurities into the surface.

Since it is uneconomical to change the type of abrasive for each type of surface, modern machines are often equipped instead with variable speed wheels. Low carbon plate, for example, could then be cleaned at low wheel

speed while the alloy alloy or high carbon plate could be de-scaled at higher wheel speed with greater impact energy.

one advantage of centrifugal blast over other nonautomated methods is the unifomity of the prepared surface. In order to realize this consistency, the operator must add new abrasive at regular intervals each hour or at least once each 8-hour shift. If large quantities of new abrasive are added at one time, the profile height will increase, production rate will decrease, and the rusty pits may not be cleaned as effectively. The desirable procedure is add abrasive as the fines are removed in the dust separator and thereby maintain a reasonably consistent working mix.

in addition to dust Separation, means for removal of oil, grease, and other contaminates from the abrasive should be provided.

Centrifugal blast cleaning of steel prior to fabrication has several advantages<sup>(118)</sup>:

Ž Defects in the steel my become evident after blasting.

- Layout for fabrication operations is more accurate.
- Burning and cutting speeds are increased.
- Tcol life is improved.

Ž Welds are of higher quality.

The need for blast cleaning after fabrication is eliminated or reduced.

In shipyards a priming system is almost always put in line with the blasting machine, to coat the blasted pieces with a primer which protects the steel from rust during fabrication.

In sane shipyards, enclosed facilities have been provided for centrifugal blast cleaning of large ship sections (Figure 3 .1).

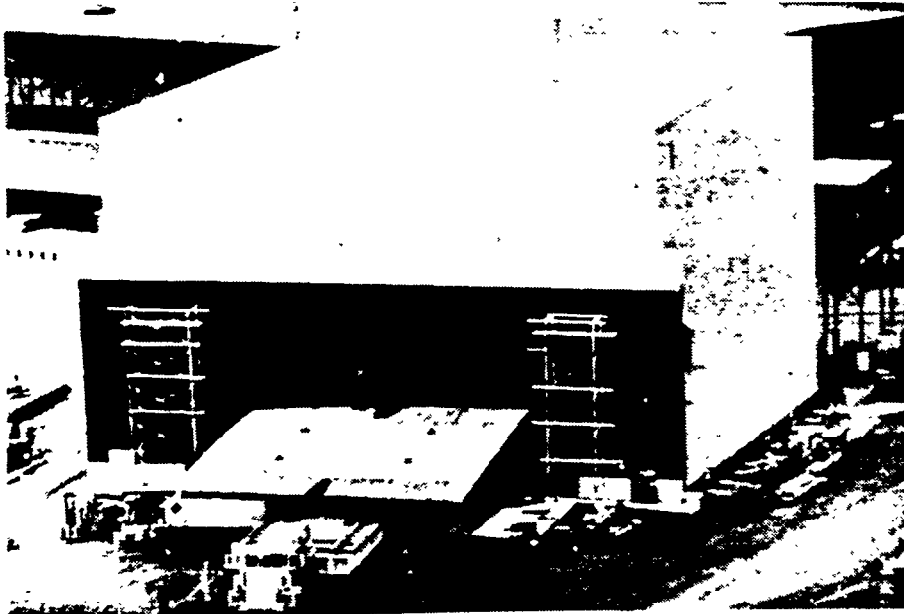


FIGURE 3.1: Exterior view of machine for cleaning large pre-fabricated ship sections. A deck section loaded on a trailer is shown entering the machine.

3.1.1.2 Nozzle Blasting with Metallic Abrasives - For metallic abrasives to be economically used they must be recycled. The most common method of doing this is to enclose the air nozzle system in a blasting cabinet or building. The blast cabinets are used for small parts. Enclosed facilities can be designed to handle any size unit which meets the manufacturing scheme of the particular shipyard.

#### 3.1.1.3 Equipment Variations

A. Portable nozzle equipment with a vacuum return to eliminate dust and recycle the abrasive is available. The two basic types of air blasting vacuum recovery systems -- pressure blasters and suction blasters -- are discussed in some detail by Baldwin<sup>(19)</sup> and Bennett<sup>(120)</sup>. Figure 3.2 shows a typical portable pressure blaster. Smaller scale units weighing only about 7 Pounds have also been developed.

The pressure-type units provide greater production rate, but the abrasive must be metallic grit or shot or a recyclable non-metallic such as alumina or garnet. These metallics and non-metallics are sometimes mixed in order to prevent abrasive "lumping" in those cases where moisture is a problem.



FIGURE 3.2: A portable dust-free pressure blaster with automatic abrasive cleaning and recycling.

(Courtesy of Pauli & Griffin)

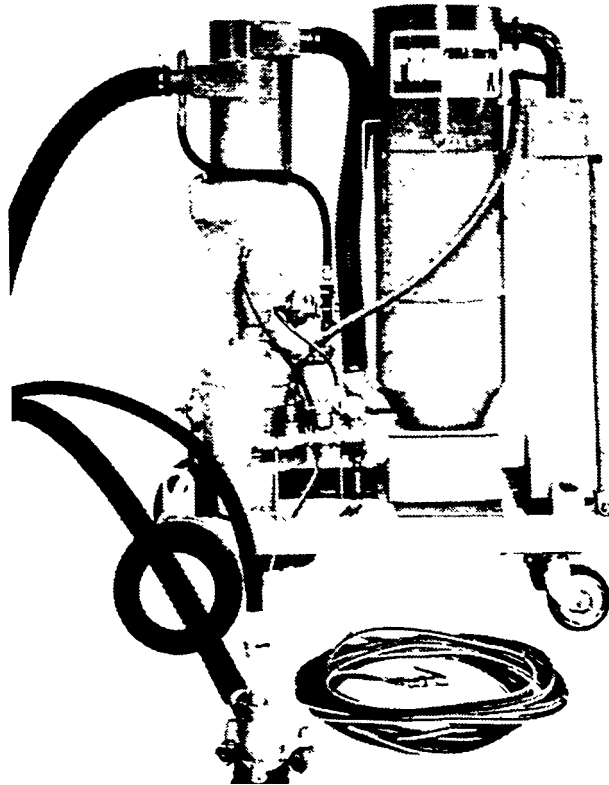
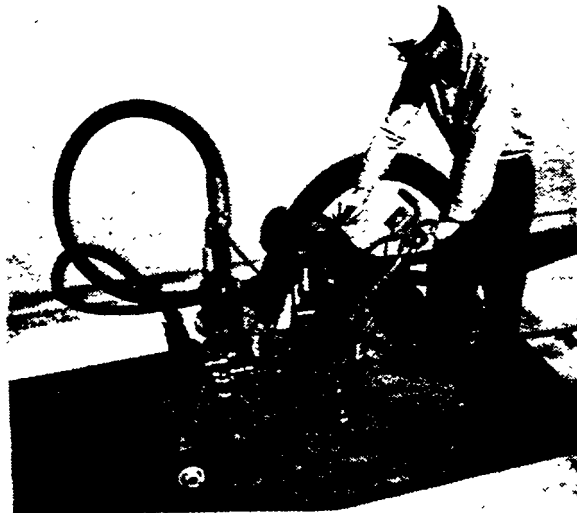


Figure 3.3 shows a "push mower" style air nozzle vacuum blaster for use on ship decks.



**FIGURE 3.3: Push Mower Type  
Vacuum Recovery Blast Machine**

(Courtesy Vacu-Blast Corporation.)

Another system<sup>(10)</sup> uses steel shot which is blasted against the hull surface through a hose a a traveling boom. The used shot, old paint, and marine growth are collected by a vacuum recovery unit.

A blasting unit has recently been designed to use a magnetic recovery of the abrasive<sup>(108)</sup>. Its usefulness to the shipbuilding industry must still be determined.

B. Portable centrifugal blast machines<sup>(1, 19)</sup>, first developed in the 1960's, have become a commercial commodity only within the past five years. Even now, "airless centrifugal blasting" generally denotes a large blasting cabinet or room to where the working must be transported. Environmental pressures and regulations prompted the development of portable wheel units. shipyards, in fact, were the first large consumer of these devices because of the large flat areas of ships were coductive to using this style of equipment. Simplifications and refinements on earlier machines have the portable centrifugal blasters econonically competitive with conventional air blasting for many shipbuilding applications.

Hull bottom cleaners incorporating an up-blast design have been developed using two wheels that will clean a swath approximately 48 inches wide (Figure 3.4).

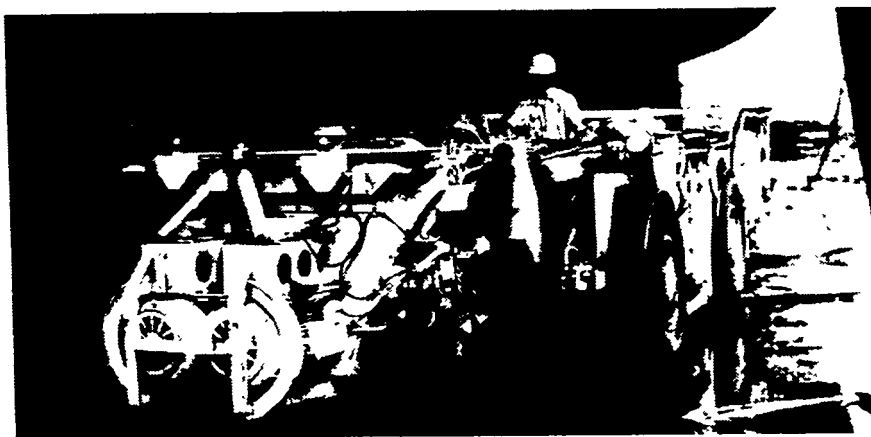


FIGURE 3.4: A dual wheel hull bottom cleaner.  
(An off official U.S. Navy photo courtesy of  
Wheelabrator-Frye, Inc. )

FIGURE 3.5: Two wheel unit can be mounted on a hydraulically operated boom for cleaning the sides of ship hulls. (An official U.S. Navy photo courtesy of wheelabrator-Frye, Inc, .)

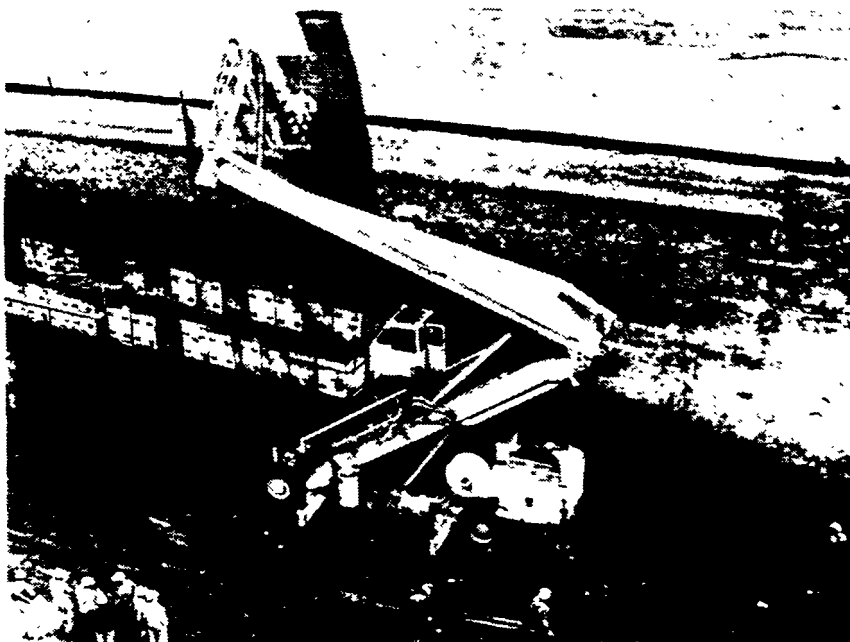


FIGURE 3.6: Close-up of the head of a hull side cleaner shows before and after surface condition. (An off official U.S. Navy photo courtesy of Wheelabrator-Frye, Inc.)

Similar two wheel machines have been designed for cleaning the sides of hulls (Figures 3.5 and 3.6). These units are mounted on a boom carried by a large truck. Because of its 80-foot reach most of the ship hull cleaning can be done from dockside.

Centrifugal deck cleaners come in a variety of sizes. Large, mobile, self-propelled units which clean a 48-inch path were first used on aircraft carrier decks in 1975 (Figure 3.7). Commercial models (Figure 3.8) of similar size and smaller, more maneuverable single wheel units (Figure 3.9 ) which clean a 20-inch swath are now in routine service.

FIGURE 3.7: A large ship deck cleaner cleans a swath about 48 inches wide. (An official U.S. Navy photo courtesy of Wheelabrator-EY Ye Inc. )

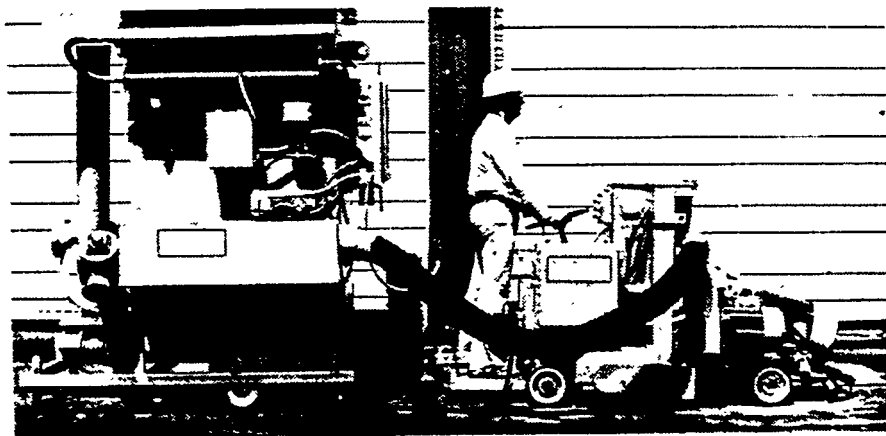


FIGURE 3.8: Large self-propelled centrifugal blast unit used on **Ship** decks . (Courtesy Porta-Shotblast).



FIGURE 3.9: Single wheel deck cleaner cleans a swath about 20 inches wide.  
(An official U.S. Navy photo courtesy of Wheelabrator-Frye, Inc.)

Very small single blast wheel units which blast an 8-inch wide swath have just recently been introduced. these portable are well suited for touch-up work and for cleaning weld seams on both vertical and horizontal surfaces.

Certain advantages and limitations common to all of the portable centrifugal blasters are summarized below.

Advantages:

Ž Pollution Free and Dustless --There is need for special clothing aside from safety hats and goggles. Nearby mark can progress uninterrupted. Cleanup becomes a minor task.

**Speed** -- Because centrifugal wheels deliver much more abrasive per hour than air nozzle systems, more surface can be prepared usually with fewer operators.

Uniformity of Surface -- Because these systems, especially the larger ones, are semi-automated, a consistent degree of surface cleanliness is more easily obtained.

Ease of Transport -- Portable centrifugal machines are easy to transport job to because of the their compactness.

Reclamation of Abrasive -- Total abrasive costs can be reduced by recycling metallic abrasives.

Flexibility of Surface Condition -- Since metallic abrasives come in a wide variety of hardness, shape, and size, and size these portable machines hold a small amount of abrasives, the abrasive can be adjusted to suit the conditions of each particular job.

### **Limitations:**

- "Lumping" of Abrasive -- When used under wet and humid conditions, metallic abrasives tend to lump. **Sometimes** addition of aluminum or garnet to the working **mix** helps to avoid this problem.
- Obstructions -- Although the smaller hand-held wheel blasters provide some flexibility, Wheel blast equipment is not very adaptable for blasting corners, fillets, or other irregular and hard to get at areas. These places must be done with an air nozzle.

- **More Complicated Equipment** — The maintenance on centrifugal units is more **sophisticated than on air nozzle** systems .
- **Maneuverability** — The **centrifugal blasters are not as** readily passed from compartment as an air nozzle.

In spite of their limitations, environmental pressure and improved designs will continue to make portable centrifugal blasters more attractive.

### 3.1.2 Wet Blast Cleaning Methods

Wet blast cleaning employs water at high pressure, up to 10,000 psi and low volume, 2 to 51 gallons per minute, to clean a metal surface for painting. On some types of equipment an abrasive can be injected into the water stream.

#### 3.1.2.1 Various Water Blasting Methods

The basic water blast unit consists of an engine driven pump, inlet water filter, pressure gage, hydraulic hose of adequate working pressure, pressure gun, and nozzle combination. The equipment should have a pressure release trigger and basic nozzles for various types of sprays. Long lengths of hose may be used (200-300 feet) without serious loss of pressure.

A clean filtered water supply is taken into an engine-driven stainless steel pump which increases the water pressure and conveys this pressurized water through a hose to a handheld gun with a small orifice. Generally there are two types of water blasting - low pressure and high pressure. Low pressure water blasting involves pressures up to 2,000 psi and is sometimes referred to as "power washing". The low pressure "power washer" is best suited for the removal of oil and grease accumulations and normally uses a detergent type inhibitor. High pressure water blasting, due to its higher production rate, is more widely used. Maximum cleaning rates are acquired by pressures up to 10,000 psi and at 10 GPM. The most common settings, however, range from 3,000 to 6,000 psi at 8 GPM. This pressure

allows the operator more comfort and less fatigue, thus producing greater overall performance. (See Section V.E. )

Steam cleaning is another variation of water blasting. It employs hot water, detergents, and sometimes alkali to remove dirt and grime deposited on the top of existing paints. Alkalinity can be adjusted to remove oxidized paint, leaving the sound paint relatively intact. It may be followed by spot blast cleaning. Several types of proprietary mixtures and equipment are available, often based upon various sodium silicates, phosphates, and detergents. The equipment for steam cleaning is relatively simple and portable. Overspray, of course, must be avoided, and the alkaline residue must be removed by thorough rinsing. Wet chemical methods of cleaning are discussed in Section 3.1.3.2.

#### 3.1.2.2 Wet Abrasive Blasting

There are many types of abrasives which can be used in wet blast cleaning, the most widely used being sand. The type and size of abrasive is directly related to the rate of cleaning, and the surface roughness. Particles which are too small or too large for the type of surface being cleaned can slow production.

The various wet abrasive blasting systems can be categorized as water curtain, sand or abrasive injection, intermediate and steam/abrasive.

##### 3.1.2.2.1 Water Curtain

The water curtain method of containing dust and flying abrasive involves a ring of water around the central blast nozzle. The abrasive is projected against the surface to be cleaned by means of compressed air as in dry abrasive blasting. A separate hose delivers the water to the nozzle. In this method abrasive and water emerge from separate orifices. There is little loss of abrasive velocity leaving the nozzle thereby maintaining the same high cleaning rates as those achieved by dry blasting.

##### 3.1.2.2.2 Abrasive Injection

In the abrasive injection method of wet abrasive blasting, the abrasive is injected or aspirated into the water stream at the nozzle.



It must necessarily be introduced after the water is pressurized to avoid pump damage. Figure 3.10 shows a typical abrasive injection unit.

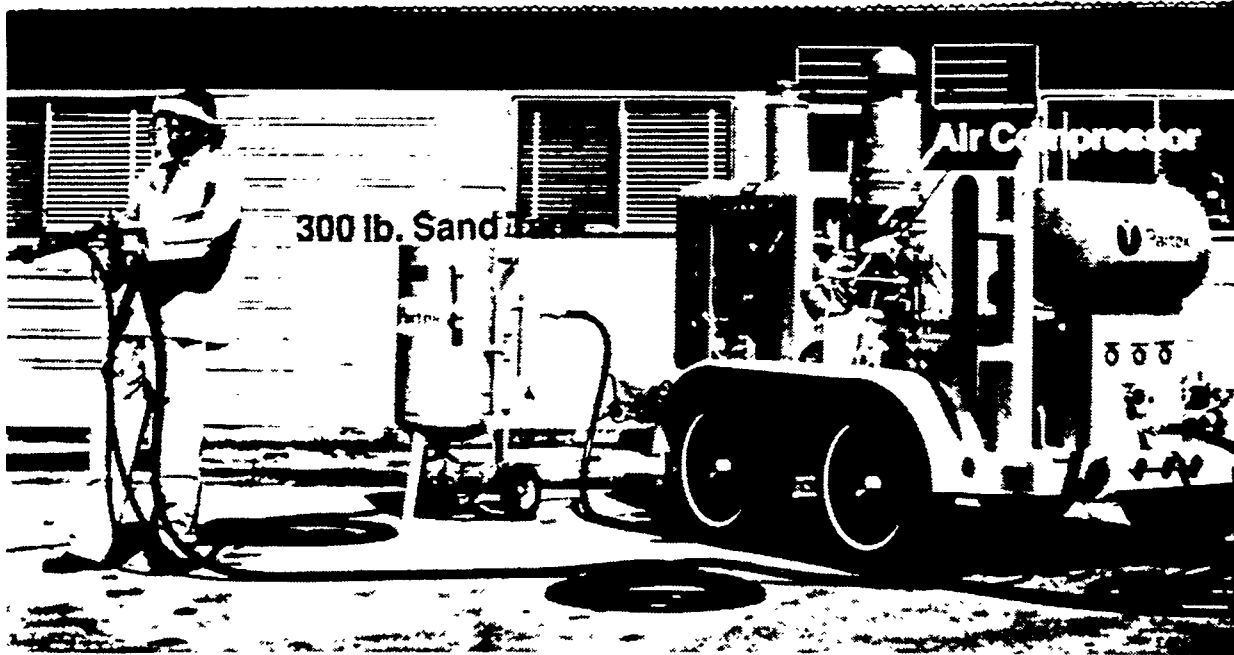


FIGURE 3.10: A typical abrasive injection blast unit.  
(Courtesy of Partek Corporation)

#### 3.1.2.2.3 Intermediate

Whereas the water curtain entails only the small amount of water necessary to contain the dust, abrasive injection primarily uses water with only enough abrasive to clean the tightly adherent contaminants. Between these two extremes are a variety of systems using different percentages of abrasive and water, such as a slurry. Each of these configurations excels under a different set of surface conditions. This diverse applicability makes the Ewer systems, with variable abrasive/air/water ratios, more versatile; but greater operator knowledge and skill are required. For description of a vowel system using abrasive, air and water see Section 3.2.1.

The addition of abrasives of the water stream, although complicating the clean-up procedure somewhat, significantly improves production and the achievable degree of cleaning. In fact, without the

abrasive, it is impossible to etch the surface or to remove tight rust and mill scale. Table III gives the average cleaning rates for hydroblast cleaning with or without <sup>(121)</sup> sand. As a general rule, pressurized hoppers are necessary to force the abrasives into the water stream, and these hoppers are subject to clogging.

TABLE III

COMPARISON OF CLEANING RATES (Square Feet Per Hour)  
FOR WATER BLASTING WITH & WITHOUT SAND INJECTION

SURFACE CONDITION	0-2,000 psi @5GPM		3,000-6,000 psi @ 6-8 GPM		10,000 psi @ 10 GPM	
	Water Only	Sand	Water Only	Sand	Water Only	Sand
Easy to clean, dusty settlement, flaky flat surface, light oil or grease.	150	200	350	<b>450</b>	<b>500</b>	650
Average rusty surface, angles and piping	75	100	200	<b>225</b>	<b>250</b>	350
Heavily corroded surface rust scale, irregular shape.	20	25	75	<b>100</b>	<b>125</b>	175

NOTE: Higher pressures require operator fatigue consideration% all pressures require access to work, sure, sound operator footing. *Figures* may vary somewhat with exact cleaning requirements.

The overall performance of water blasting with or without abrasives depends on the abrasive, inhibitor, operational technique, surface condition, and degree of cleaning required.

#### 3.1.2.2.4 Steam/Abrasive Blast

A Steam/Abrasive Blast technique which uses steam to propel the abrasive has been developed by the Japanese<sup>(63)</sup>. The Use of steam instead of water results in a shorter drying time and a significant decrease in the amount of rust formation in comparison with other wet blast methods. However, three major obstacles seem to preclude its widespread use at this time. First, the cloud produced by the steam obscures the operator's view of the work. Secondly, steam, because of its high temperature and release of energy upon condensation poses special safety problems. Third, in this era of energy consciousness, steam/abrasive

blasting is one of the most energy intensive of surface preparation.

### 3.1.2.3 Advantages and Disadvantages of Water Blasting and Wet Abrasive Blasting

Dust - One of the biggest problems associated with dry blasting, the dust it creates, can be controlled through the use of either a water jetted system or a water **curtain**.

Cleanliness - Wet blasting tends to remove residual salts from the pitted steel surfaces that cause the breakdown of protective coatings and renewed corrosion<sup>(38)</sup>. A study has shown that combined abrasive and water blasting is found to be more effective in cleaning rusty steel, especially for the removal of salt contaminants, than dry abrasive **blast cleaning**<sup>'33'</sup>.

Excess Water - Water Volume may present a water disposal problem depending upon the size and condition of the surface.

Flash Rusting/Inhibitors - To prevent oxidation or flash rusting a suitable inhibitor is *usually injected into* the blast hose or applied after blasting. It is often preferable to apply the inhibitor solution after water blast thereby minimizing operator exposure, saving inhibitor, reducing problems of liquid pollution. Inhibitors include soluble chromates, phosphates, nitrates and molybdates<sup>(116, 117)</sup>. Certain inhibitors when dry, leave salts that could produce adhesion problems for protective coatings. Therefore, it is essential to insure that the inhibitor is compatible with the paint system to be applied. Another solution to the problem of flash rusting is to apply a paint system compatible with a wet surface. Such paint systems are now being developed<sup>(69)</sup>.

Production Rate - There is some difference of opinion as to the relative production rates of wet abrasive cleaning versus conventional dry blast cleaning. Table IV shows that the cleaning rate for a particular sand injection system appears to be faster than that of a typical dry blasting unit. However, when one considers the fact that a man can work all day using a 3/8 inch dry blasting nozzle without undue fatigue, while 10,000 psi water blasting would be tiring after 30 to 60 minutes, the dry blasting operation could actually be faster.

TABLE IV

COMPARISON OF PRODUCTION RATES BETWEEN A  
TYPICAL WET-BLAST SYSTEM & DRY SAND BLASTING

EQUIPMENT	SURFACE CONDITION (STEEL)			
	(A) Overall Rust with Heavy Pitting	(B) Loose Mill Scale, Fine Rust, No Pitting	(C) Tight Mill Scale, Little or No Rust	(D) Tight Paint Negligible Rust
	SQUARE FEET	SQ. FT. BLASTED PER HOUR TO WHITE METAL		
Sand injection system 10,000 psi @ 10 GPM. 3001b. pressurized sand tank consumption 700 lbs/hr. 30-60 mesh	<b>120 (1)</b>	<b>240 (1)</b>	<b>245 (1)</b>	<b>250 (1)</b>
100 psi continuous dry blaster. 3/8" nozzle 240 cfm air compressor sand consumption -- 1300 lb/hr. 30-60 mesh sand	<b>57 (2)</b>	<b>216(2)</b>	<b>168(2)</b>	<b>N. A.</b>

- (1) Based on actual tests. (Note: Differences in surface conditions, operator technique, etc. can result in variations in performance. No performance guarantees are implied. )
- (2) Based on rates from Table 3 of National Association of Corrosion Engineer's publication "Industrial Maintenance Painting". 3rd edition.

Costs - It is difficult to compare wet abrasive cleaning costs with other surface preparation methods because of applications. Equipment and labor costs, surface conditions, and various production rates all vary. Compared to hand tool cleaning, the higher equipment costs of Wet abrasive blasting are more than compensated in lower labor costs per square foot, a cleaner surface, and higher production rates. As a general rule the total cost of wet abrasive blasting is slightly higher than dry abrasive blasting.

Safety - Due to the high water pressure associated with some wet blasting operations, caution must be practical in accordance with OSHA and other applicable regulations. The operator must be properly trained and informed as to the correct and safe procedure in the operation of the equipment. Sound and safe footing, proper scaffolds, and outer protection consisting of a rain suit, face shield, and gloves should be provided. As with any high pressure force, caution should be used to protect other nearby workers and equipment.

### 3.1.3 Sane Non-Blast Methods

conditions often exist where blast cleaning is impractical because of safety, pollution, protection of adjacent equipment, cost, or need. The use of and power tools or chemical cleaning, which are the alternatives to blast cleaning may be necessary. These are described below.

#### 3.1.3.1 Power and Hand Tool Cleaning

Hand tool cleaning consists of removing loose mill scale, loose rust, and loose paint by brushing, scraping, chipping, or a combination of these methods. Some of the common tools are: wire brushes, scrapers, chisels, knives, chipping hammers, and in some instances, emery or sand paper.

For power tool cleaning, the rotary wire brush is widely used. Other tools in frequent use include impact tools and grinders. Chipping hammers are sometimes necessary when considerable rust scale or heavy paint formations must be removed. Great care must be exercised in using them, however, because of their tendency to remove sound metal and leave sharp burrs which will cause premature paint failure. Recent developments in power tool cleaning include abrasive impregnated nylon filaments, and the use of elastomer bristle supports. The needle gun has also been found effective in medium to heavy de-scaling and de-scaling in SSPC tests.

Hand tool or power tool cleaning should be preceded by solvent cleaning to remove oil and grease, and should only be expected to remove loose rust and mill scale. Care must be taken not to overbrush or burnish the surface so as to interfere with proper paint adhesion.

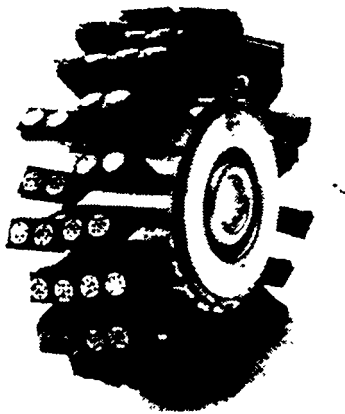
Pneumatic abrasive tools are the type used by most yards, although some do use electric abrasive tools. Many yards are either switching or planning to switch to air power for most of their surface preparation work.

Several reasons for this move to pneumatic tools are:

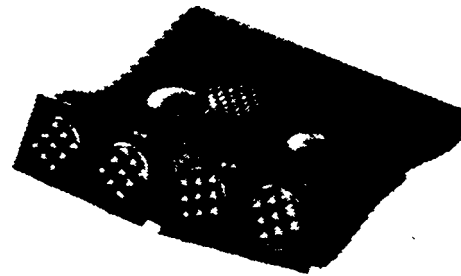
- Air powered tools are light, small, and easy to handle.
- They do not overheat.
- The maintenance requirements are low.
- There is no danger of electric shock.

New centrifugal flagellating devices have only been on the market about five years. Tungsten carbide shot is metallurgically faced on

metallic support bases which are mechanically attached to a strap. These strap assemblies are fitted into a slotted 4" diameter aluminum hub to form the peening wheel. The hub can have a length from about 1" to 50" and therefore can be adapted to hand-held units or larger automated systems. The cleaning rate for scale **removal is in the range of 2 to 30 ft<sup>2</sup> per** minute, which is about 1.5 times slower than abrasive blasting. This device is especially suited for large flat surfaces but is of limited use around such obstacles as bolts, rivets, and corners. For these rough or uneven areas a needle gun may be used satisfactorily. Needle guns, however, clean three times slower on flat areas than the rotary peening tool.



A rotary peening flap assembly.



A peening wheel comprised of many assemblies.

FIGURE 3.11

(Courtesy of 3M Company)

Although the peening wheel is technically a power tool, the surface resulting from this treatment very closely resembles a brush-off or commercial blast, particularly for intact mill scale. Exposure tests conducted by the SSPC have shown surfaces prepared by the rotary flap to be adequate for short term exposure with several primers. The performance of coatings over roto peened surfaces cannot adequately be compared to blast cleaned surfaces until these exposure tests have run their course.

A brush device similar in principle to the rotary peen flap has recently been developed<sup>(136)</sup>. Abrasive particles are bonded to a nylon web which is fashioned into a roll or disc. The sponginess of the nylon

webbing provides same adaptability to varying contours. These brushes are used on coil coating lines where the **required** surface profile is very minimal. Tests are now being run by the SSPC to determine their applicability to structural steel where rust and mill scale must be removed leaving a suitable anchor pattern.

3.1.3.2 Chemical Cleaning ( 1 1 6 , 1 2 3 3 ) - Chemical surface preparation includes such methods as pickling, solvent degreasing, water blast, alkali cleaning, and steam cleaning. Although water blasting **and** steam cleaning could be considered chemical treatments, these methods are discussed in Section 3.1.2, Wet Blast Cleaning.

#### 3.1.3.2.1 Solvents

Solvents are used **to** dissolve and remove deposits on steel surfaces. Ordinary cleaning with hydrocarbon solvent does not remove corrosive salts such as chlorides, sulfates, and detrimental weld flux residues. However, these can be removed by special solvent cleaning methods such as high-pressure water blast cleaning, steam cleaning, or washing with a phosphate solution.

Solvent cleaning is expensive if done properly. Precautions must be taken to avoid recontamination of solvent, or the operation will result in spreading a film of oil and grease over the entire surface. Care is also required to minimize fire and toxicity hazards.

There are some safety features that those who solvent clean should keep in mind. Most solvents used for - cleaning have low flash points, and therefore present a fire hazard. In addition, many materials are toxic. Therefore, solvent cleaning should be used only in well ventilated places or outdoors. The operators should be protected from vapors, as well as from liquid contact with the skin. Local environmental regulations may also limit the use of this method.

#### 3.1.3.2.2 Pickling

Pickling is a process used to remove oxides and scale from new steel by immersion in dilute acid. Warm sulfuric acid is usually used in the U.S. because of its low cost, low volatility, and effectiveness. Sometimes other acids are used such as: hydrochloric, phosphoric, nitric,

hydrofluoric, or methods like electrolytic pickling in an acid or alkaline bath, hydride de-scaling, and pickling in baths of molten salts.

The outer layer of scale is almost insoluble in sulfuric acid. However, the pickling acid penetrates through the cracks of the outer scale layer and dissolves the underlying metal-rich layers. The hydrogen evolving from this reaction then blows off the outer scale in flakes. Next, the pickled metal is rinsed in cold or hot water and is often further prepped for painting by a final rinse in dilute phosphoric or chromic acid or mixtures of these. This final passivating rinse retards rusting.

Most high performance Coating systems specify blast cleaning or pickling. However, pickling is not as desirable as blast cleaning for those coating types that rely heavily on mechanical anchoring for adhesion. Atmospheric exposure tests conducted by SSPC generally indicate more undercutting failure at a scribe on a pickled surface than on a blast cleaned surface.

#### 3.1.3.2.3 Citric Acid Cleaning

The ammonium or triethynolamine (TEA) citrate process is used to remove both magnetite (one of the components of mill scale) and copper from boilers and other equipment by using a solution of citric acid. An investigation was conducted to optimize the process for copper dissolution and steel passivation. In this practice, the citric acid is **ammoniated to pH 3.5** - 4.0 at 200°F ( 93°C) to dissolve magnetite. Use of this method was reported to save significant amounts of water and time. Job experience has shown that ammonium citrate solvents are highly versatile, and that they can be very effective in removing operationally formed deposits.

adaptation of the TEA/citric acid process to ship surface preparation was investigated in depth by others in an Avondale/Marad project<sup>(131)</sup>. This project demonstrated the compatibility of most marine coatings with the resultant cleaned surface.

#### 3.1.3.2.4 Gelatinized Acids

Gelatinized phosphoric acid solutions have been used for many years for removing rust. These compounds, e.g. Naval Jelly, have



limited use in large structures because of cost, safety, and pollution considerations.

#### 3.1.3.3 Thermal Methods

Thermal shock is often sufficient to remove or convert mill scale. Surface preparation specification, SSPC-SP 4, "Flame Cleaning of New Steel" describes a process for the dehydrating and removal of rust, loose mill scale, and some tight mill scale by passing a flame over the surface. The surface is then wire brushed to remove all loose materials. Because of cost effectiveness and limited use, the SSOC is considering dropping this specification.

A high-temperature, high-velocity blast of air has proven effective in removing road markings. The cost effectiveness of this process for removing paint from large steel structures has yet to be proven<sup>132)</sup>.

### 3.2 Promising New Surface Preparation Methods and Procedures

In the current technological development of surface preparation methods, a number of approaches can best be characterized as new. Some of these fall within of the foregoing classifications but are discussed here for emphasis. They include new air/sand/water combinations, improved water-blast methods, use of zinc shot blast and other corrosion-inhibitive abrasive blast media. These are believed to have appreciable potential. for much broader practical application in the industry within the short-term future.

Certain other novel approaches show sufficient promise to warrant being noted here, although still lacking in sufficient small-scale trial data to justify a firm recommendation for further investigation at this time. These methods include the use of cavitation, lasers, xenon lamps, explosives, hot gas, ultrasonic, bacterial cleaning, and magnetic propulsion of abrasives.

### 3.2.1 Air/Sand/Water Combination

3.2.1.1 Description - At least one recently developed process employing air, sand, and water is sufficiently versatile in its equipment, mode of operation, and results to be considered a separate and very promising method of surface preparation.<sup>(141)</sup> It is quite distinct from either conventional water or wet abrasive blast cleaning methods. Advantages include freedom from silica dust and removal of all detectable sulfates and other electrolytes ordinarily left by dry blast cleaning.

A unique combination of features includes a large volume of air (300 to 400 cubic feet per minute) into which one to two gallons of water per minute can be entrained with or without a corrosion inhibitor. Sand or other abrasives may be added at 200 to 400 pounds per hour and the mixture is delivered through an open-ended, cone-shaped, wide-mouthed nozzle (0.5 to 1 inch in diameter) at pressures which can be varied from 15 to 100 psi. In various trials the rate of cleaning has been estimated to be from 50 to 200 square feet per hour depending on the surface, with reported removal of single coats of paint at rates as high as 300 to 450 square feet per hour.

Each of the quantities, air-sand-water, is independently variable so that the system can be used without sand at low pressure merely to wash down surfaces. By increasing the pressure and sand loading a little, just the finish coat can be removed. A further increase in pressure results in the removal of successive coats or blast cleaning to white metal.

The system is contained on a large vehicle which includes a water tank, a generator, two sand or grit hoppers, and a tank containing inhibitor (Figure 3.12 ). The only outside facility needed is a source of clean water. Two blasting nozzles can be operated from one vehicle and up to 300 feet of pressure blast hose can be used. The operator at the control panel is connected by a throat microphone "intercom" system to the blaster for rapid adjustment of each variable.

Figure.3.12: Vehicle/  
mounted air/sand/water  
unit. (Courtesy of  
KUE, Ltd.)



3.2.1.2 Demonstration - None of these units were available in the U. S.; therefore, at the time of initial- investigation, an inspection trip was made to work sites in England. since that time, somewhat similar units have reached the developmental stage in the U.S. <sup>(142)</sup> In England it was verified that removal of a single mat, multiple mats, or white metal blasting could be obtained (Figure 3.13). Freedom from rust-back was also demonstrated for this wet system in comparison with a dry blast cleaned surface, which rusted back shortly after being washed with water. Absence of sulfates after wet blast cleaning was shown by the potassium ferrocyanide paper test. A similar flexibility was observed on a blast cleaning operation on a A-1 Motorway bridge over the River Darn. Here it was desire to remove only the top coat on part of the job and to remove flame sprayed zinc on another section.

Tarps were arranged so that the washings flowed into a central sump from which the water was pumped through a second filter into the drain. Road and river traffic continued uninterrupted above and below the work. No positive air-fed mask, hood, or other special protective equipment was considered necessary other than goggles and a wet suit for comfort.

The advantages and limitations of air/sand/inter units are discussed in the following paragraphs.



FIGURE 3.13: Test plate on which white metal blast cleaning (SSPC-SP 5) and spot removal of individual costs was demonstrated.

#### Advantages

- Quality of surface — On-site tests verified the absence of soluble electrolytes after cleaning, a result which has not been observed with conventional dry or wet cleaning. Such residual salts have **been** shown to cause early paint failure.

- Versatility — Equipment enables operator to remove only the desired coats of paint, leaving the remaining coats undisturbed, **and** to obtain a white metal blast when necessary.

- Pollution control — Free silica and other dry dust are apparently absent from the blast area. For most configurations the sand can be carried away in the trickle of water and collected.

- *safety* — The nozzle area was apparently free of hazards that characterize sand blasting or high pressure water blasting.

- Operator fatigue — The operation did not appear to involve high hose thrust.

- **Communication-** Effective communication is achieved between the blaster and the operator.

- *Manpower* — Each unit operator can serve two to four blast cleaning nozzle operators.

- *Flammability* — In heavy fume areas sparking - does not seem to be a possibility.

- *portability* — System is contained on a single truck.

- Recovering toxic materials — This system should facilitate on-site removal and collection of Potentially toxic coating (anti-fouling, lead paints, chromates, etc.) Which are being removed.

- Feathering — It is claimed that the straight lance nozzle (instead of the usual Venturi-type) fans out the water producing a "feathering" of existing coating and improving visibility. This results in better surface quality.

- **Mastics** — **In** removal of bituminous, coal tar epoxy, or other mastic coatings with wet blast methods it is claimed that the water keeps the coating cool and relatively brittle, so that the abrasive is less likely to simply bounce off the coating.

### Limitations

- **Training** — As in all sophisticated systems, an operator must be properly trained to take advantage of inherent flexibilities of the system.

- **Cleaning rates** — preliminary observations indicate that cleaning rate is somewhat lower than the equivalent rate for dry blast cleaning. Down time due to operator fatigue, however, may be less.

.Equipment— Costs of equipment and of power for furnishing large quantities of air are considerable.

- **Bid quotation** — Since this is a new and unique system it would be difficult to obtain competitive bids on an equal-quality basis.

- **Inhibitor** — Tests carried out by the Paint Research Association in England indicates that the inhibitor does not have a deleterious effect on paint coatings. This factor should be verified for other contemplated paint systems. (Comparative tests are under way by SSPC with and without inhibitor, with and without air drying before flash rusting .)

- **Profile** — The compatibility between the resulting profile and specified paint systems should also be verified.

#### 3.2.1.3 U.S. Variations

U.S. variations of this method were illustrated by video tape and described at special SSPC meetings. They involve a somewhat similar unit which operates at about 1000 pounds per square inch water pressure with sand injection. Unlike the English system, this one entails remote control via micro switches of a seven-ten dry blast pot by the operator at the nozzle rather than by verbal communications with an operator. Also unlike the English method, it involves a considerable amount of sand, which sometimes has a tendency to stick to the work as a slurry.

This slurry is then **allowed** to dry and is washed off with an auxiliary nozzle at perhaps 1000 to 1500 square feet per hour.

The incoming water is used as a cooling medium for the compressed air, **thereby heating the incoming water to about 125°F (52°C)**. Instead of using inhibitor (normally a phosphate) or undergoing flash rusting, the surface could be dried off with compressed air after cleaning, but this is seldom done. Only about one to two gallons per minute of water is required, using a 1.25 inch (3.5 cm) blast hose and a nozzle size of 0.521 inch (1.3 cm).

#### 3.2.1.4 Recommended Uses

The air/abrasive/water systems can be used for such marine applications as cleaning of ship bottom and top sides prior to repainting. This should permit quick turn-around in dry docks if multiple units are used. Other possibilities include deck cleaning dry dock or at sea. Broad applications are foreseen for numerous bridges and other structures now suffering paint breakdowns in most parts of the U.S.

#### 3.2.2 Hydraulic Sand-Injection Methods

Variations of the medium to high pressure hydraulic cleaning systems (Section 3.1.2) have been recently developed in response to special needs of the Coast Guard and other marine applications. To meet these special requirements approximately ten alternative systems were compared, resulting in a set of specifications which were subsequently met by only a very few of the alternative methods.

3.2.2.1 Description. Most of the conventional methods failed because of being underpowered (operated at 500 to 1200 psi using conventional pumps) or were unable to meter the sand without clogging. Systems which meet the specification usually operate at the order of 2000 psi and work under a buddy system with two men alternating every 15 minutes. Hand signals were used between the blaster and the operator. In order to satisfy the performance requirements of the specification, unpressurized hoppers are used and two or more nozzles are operated from the same manifold. Water pressure and sand injection are adjusted according to the needs of the job. (Figures 3.14 and 3.15).

FIGURE- 3.14:

A typical marine use of the  
hydraulic equipment with  
abrasive injection.  
(Courtesy of WOMA Corporation)



FIGURE 3.15:

A portable hydraulic  
unit which meets  
U.S. Coast Guard  
surface preparation  
performance  
specifications.  
(Courtesy of  
WOMA Corporation)



### Advantages

- Pollution is reduced. This is especially important in removal of paints containing carcinogens and toxic anti-fouling ingredients.

- Flexibility – The method saves the cost of removing and replacing good paint.

- Visibility – The operator can see well enough to remove single coats of paint when necessary. It is claimed that with some coatings, such as vinyls, water can be employed alone whereas most epoxies, urethanes, etc. , require metering of sand and creation of an anchor pattern. An abrasive is needed whenever rust is present or an anchor pattern is desired or a near-white surface is necessary.

- No air needed.

- Refuse – Less sand needs to be removed than in dry blasting.

- Interference – There is less interference with other nearby work which would sometimes have to be shut down for dry blast cleaning.

- Tank and tubes – This method can be adapted to cleaning the inside and outside of tubes on boilers etc. or fitted with a vacuum jet for removal of sludge and other refuse accumulated from the cleaning of tanks and bilges.

### Disadvantages

- skill -- To take advantage of the versatility of the method, skill in operation is necessary.

- Bidding - Performance specifications and try-outs are necessary to assure proper versatility, skill, cleaning rate, and quality of surface.

- Rate - Cleaning rate has been slower than with dry blast cleaning by approximately 25%.

- Cost - Investment cost is higher than an abrasive blast unit but lower than the air/sand/water unit.

- Inhibitor - A polyphosphate inhibitor is sometimes used to prevent rust-back. It is recommended, however, that the inhibitor solution be applied only as a separate wash and not in the high pressure water stream.

- Effluent disposal - As with other systems the effluent water may contain toxic compounds from the removed paint which must be properly filtered and disposed of.

3.2.2.2 Recommendations are that the latest U.S. Coast Guard experience be reviewed and that the units which meet new Coast Guard performance specifications be considered for special marine and related applications.

### 3.2.3 Automated Water Blasting

State of Texas highway officials have developed a water jet cleaning system which does not require an operator at the nozzle. A high pressure jet nozzle is attached to a rig which is then clamped onto the bridge beam and remotely controlled by an operator on the ground. The operator can translate the nozzle along the beam and change the angle sideways and up-down to allow access to over 90% of the surface area. The developers are working to increase this percentage and the unit's overall versatility. The unit offers several important advantages. Safety is greatly improved because the operator does not direct the nozzle or support the thrust, which may be as high as 100 pounds. In addition, contrary to

the hand-held units, the operator **does** not become fatigued in a few hours, resulting in increased productivity. The automated device should produce a more uniformly clean surface and permit more precise calculations of rates and rests. Some of the Problems experienced with the automated unit are lack of maneuverability, high capital **equipment cost**, increased **main-**tenance, and the need for modifications to allow use on different types of structures.

#### 3.2.4 Zinc Shot Blasting

Zinc shot blasting (zincing) is a modification of the normal blast cleaning procedure in which metallic zinc particles are substituted for all or part of the shot, grit, or sand. The result is a thin discontinuous deposit of metallic zinc left on the freshly-cleaned steel surface during blasting. This process permits steel plates and shapes to be pre-blast cleaned with conventional equipment before fabrication.

The zinc deposit can be achieved through either a one-step or two-step operation, but the two-step process appears to be the more practical. It consists of blast cleaning with steel (or sand) particles, followed by a separate blasting with zinc particles (usually in the same equipment sequence). Alternatively, both the cleaning and the zinc deposition can be carried out together in a single stage operation. Both the one and two-stage processes have been demonstrated with both nozzles and centrifugal wheel blast cleaning equipment. Only a small portion of the zinc is transferred to the clean steel by steel particle impact. The zinc particles are recycled just as the steel shot and grit are recycled. During the recycling, zinc dust fines are removed just as steel dust is removed in the shot/grit blast cleaning operation.

The resulting zinc deposit is only about 0.05 mils (1.3 microns) thick but is sufficient to prevent rusting during the days, weeks, or months required for fabrication and Ship-building. Since zinc metal is "sacrificial" to steel, the coating need not be continuous in order to protect the steel completely.

The zinc deposit has been shown to be compatible with some conventional coatings, actually adding duration to the life of the one type

of coating (vinyl) which has been tested to date. The process was developed by the Steel Structures Painting Council some time ago in an effort to permit pre-blast cleaning of steel in the shop before fabrication without having to apply a temporary pre-fabrication primer. Unlike the present pre-fabrication primers, the zinc deposit readily permits welding, cutting, etc., and need not be removed laboriously before application of the primer and paint system used for final protection of the steel. Preliminary cost estimates indicate substantial savings in materials, time, and manpower. To date, the method has been proven in both laboratory and pilot plant, but not yet demonstrated on a full scale.

Additionally work would be necessary to demonstrate whether or not the new process, or a variation thereof, is applicable to a typical shipbuilding sequence. For example, it is not known what type of washing or cleaning would be necessary in order to remove oil, dust, etc., which now accumulate during fabrication. Such cleaning of superficial residues, however, would be much faster and cheaper than a second blast cleaning. It would also be necessary to verify the compatibility of the light zinc deposit with each subsequently applied paint system. Since compatibility (and synergism) have already been established with alkyd and vinyls, no difficulty is anticipated for other generic types of coatings used in the shipbuilding industry. The practicality must also be verified of a separate zinc shot blasting following steel shot or grit blasting, since this two-stage process would require a separate set of wheels or a nozzle application.

This process has been further described in an SSPC report<sup>(97)</sup> and in industry literature<sup>(97, 126)</sup>. Although the SSPC process itself is not patented, attempts to modify it on an industrial scale have been investigated and patented. It is considered that these modifications are minor and not essential to the success of the method. One variation developed in Denmark<sup>(27)</sup>, is the use of zinc-coated abrasives. Another variation<sup>(97)</sup> uses sand coated with zinc dust. One investigator<sup>(97)</sup> has achieved protection up to four months with the two-stage zinc blasting process in which conventional blast cleaning is used to remove rust and mill scale followed by blasting with zinc powder.

### 3.2.5 Other Inhibitive Abrasives

SSPC work indicates that although zinc is the most effective inhibitive substance to date which can be applied in blast cleaning equipment, it is not the only one. In early work a wide variety of other inhibitive materials were investigated but were found to be less desirable because of handling difficulties, toxicity, safety, shorter protection period, or necessity of removal before coating.

Subsequent to publication of the SSPC work, a modification was investigated elsewhere using a stearic acid "inhibitor" which gave temporary Protection but had to be removed from the surface before painting<sup>54, 55)</sup>

Attempts have been made to combine inhibitive phosphating treatment with blast cleaning<sup>(112, 113)</sup> Although the SSPC has explored several alternative inhibitive materials to be used in solid, liquid, or vapor form during blast cleaning, additional work would be necessary in order to determine whether or not any of these have promise in comparison with zinc shot blasting.

### 3.2.6 Carbon Dioxide Pellets

Preliminary work has indicated that it may be possible to use carbon dioxide pellets as a blast cleaning medium in those areas where clean-up of spent abrasive is a problem<sup>(52, 53)</sup>. No reports or accounts could be obtained, however, of successful use on structural steel under controlled conditions comparable with those in shipbuilding. At the various meetings sponsored by the SSPC to discuss new surface preparation methods, verbal reports were presented indicating a series of problems which appear to render this method impractical for shipbuilding or other structural steel applications; the pellets were not effective in removing mill scale; visibility problems were presented by fogging at the nozzle; pellet-forming equipment was reported to be prohibitively expensive and difficult to maintain; problems were foreseen in ventilation and condensation of water. Attempts to arrange a demonstration by the inventor were unsuccessful.

### 3.2.7 High Velocity Ice Particles

This approach has been reported<sup>(98)</sup> to be effective in removing fouling and paint from ships. The process is claimed to be more efficient than metallic shot in removing biofouling but less efficient in removing paint as well as probably impractical for use on new steel. Because of its pollution-free characteristics, the use of ice may eventually assume a larger role in cleaning, particularly in the refurbishing of hulls.

### 3.2.8 Lasers and Xenon Lamps

Preliminary tests<sup>(60)</sup> have shown that scale or other adhering deposits can be removed, at least from small specimens, when they are subjected to thermal shock or chemical decomposition using a laser beam. When rusted steel was exposed to laser beams of several kilowatts, the hydrated oxides were changed to a dense, hard scale of magnetite ( $\text{Fe}_3\text{O}_4$ ), which could then be removed. It may prove practicable to carry out such operations in a reducing atmosphere to produce a readily removable layer of metallic iron. Although having potential, laser cleaning is not believed likely to have an impact on the cleaning of structural steel in the foreseeable future because of requirements of energy input and equipment development.

can be alleviated somewhat by using xenon lamps<sup>(127)</sup>, which are more efficient than lasers in delivering energy to the surface. As with lasers, temperatures are of the order of 3000 °F (1700°C). A recently developed proprietary xenon system, known as FLASHBLAST<sup>TM</sup> has shown great promise for removing thin layers of paint from a surface. This system emits very intense, ultra-short pulses of light with sufficient energies to vaporize or chemically alter most non-metal substances. Due to the short duration of the pulses, the effect is restricted to a layer approximately 0.001" in thicknesses with little or no effect on the underlying material.

A typical FLASHBLAST<sup>TM</sup> system consists of a power supply, a control module and one or more flashlamp heads from which the light pulses are emitted. The power supply provides intense electric discharges which

are **carried** through flexible cables to the heads where they give rise to the emission of short, intense pulses of light from Xenon flashlamps. The weight of the flashlamp heads is only a few pounds and the flexible cables can be as long as 100 feet, permitting work on fairly large surfaces or objects without moving the heavy power supply module. The flashlamp heads must be in near contact with the surfaces under treatment since the intensity of the light drops rapidly with increasing distance from the lamps.

Applications which have been studied experimentally so far include removing thin paint layers from metal and underlying paint layers. Because of the high degree of control afforded, the technique can allow precise, select removal of outer layers of materials without disturbing the inner substrate or paint layer. Additional work is planned to develop and evaluate full-scale systems and to determine the practicality and production rate for field applications.

#### 3.2.9 Plasma - Hot Gas

A combustion unit<sup>(140)</sup> which uses a mixture of liquid propane and compressed air to produce a blast of hot gas has been used extensively to remove road markings. The high temperature, 3000 °F (1700 °C), **is sufficient to vaporize many organic paint films or at least char** them to the point where the high-velocity air blast can blow the surface clean. Treatment of a paint film with the hot air blaster makes any **remaining** paint easier to remove by conventional sand blasting.

Use of this unit in the surface preparation of previously painted steel structures is not widespread. However, it shows considerable promise in those situations where a heavy vinyl or thermoplastic coating is to be removed, since the abrasive has a tendency to bounce off rather than fracture a thick flexible coating.

In preliminary field tests<sup>(132)</sup> some problems were found with this system. The primer is not completely removed by the hot air blaster and must be removed by conventional abrasive blasting. The five-foot long handle, necessitated by the intense heat and fumes, limits its use in confined areas and contributes to operator fatigue. Clearly the safety problems related to fire, noise, and ventilation must be considered.

Although currently limited in its use on steel structures, **this** hot gas unit has potential to solve specialized surface preparation problems. For example, the combined operation of first vaporizing or charring like old paint with the hot gas blaster followed by conventional abrasive blasting may, in some instances, prove beneficial. Field work must be done to test this approach.

#### 3.2.10 Ultrasonic Cleaning

**Ultrasonic** cleaning is in widespread use in speeding the Solvent cleaning of small parts, etc. Although it has been proposed for cleaning of larger Structural steel, no unit larger than about 75 gallons capacity has been reported<sup>(128, 129, 130)</sup>.

#### 3.2.11 Cavitation

Cavitation **is** best known as a destructive phenomenon which results in metal loss on a near improperly designed ship propellers, pumps, etc. Efforts have been directed toward using this effect in the cleaning of steel<sup>(45, 133)</sup> By modifying a water blast cleaning unit to maximize cavitation, the energy transfer to the steel is potentially much greater than with conventional water blast equipment. The technique has been successfully utilized in boiler tube cleaning, rock drilling, and in removing underwater fouling from ship hulls. The technique of controlled cavitation also offers the possibility of certain advantages for surface preparation of structural **steel**.

The efficiency and productivity of cavitation jetting depends on the operating pressure and flow rate, design of nozzle, size of orifice, standoff distance, and angle of impingement. The application of this technique to surface preparation is still in the early development stage. Current research efforts focus on a number of different areas pertaining to surface preparation, as well as related areas such as steel cutting, and concrete rehabilitation. A government-sponsored program is Concentrate on developing units which produce less than 50 pounds of operator thrust. As with conventional high-pressure water blasting operator fatigue is a limiting factor. The goal is to provide hand-held devices for



complex structures and inaccessible areas. Researchers anticipate that rates for producing a clean, paintable surface (i.e., removing loose paint, dirt, and loose rust) will range from 50-200 square feet per hour. These are based on the use of current technology. Additional research is directed at advancing the technology to achieve the more difficult task of removing hard rust and intact paint, and producing a surface profile at rates approaching those above (i.e., 100 sq. ft./hr. ).

In addition to the hand-held tools, efforts are planned to develop high production units which would include features such as multi-nozzle arrays and automatic translation and thrust support. A further objective of the sponsors is to devise a means for recovering paint and rust removed from the surface using suction, vacuum, or other auxiliary equipment. The U.S. Air Force is investigating the use of cavitation to remove paint from aluminum. The technique's ability to control the depth of erosion could allow removal of the topcoat alone, leaving the primer intact and avoiding damage to the aluminum substrate.

#### 3.2.12 Bacterial Cleaning

The Japanese<sup>(110, 114)</sup> have been experimenting with biological methods of cleaning steel. Scale and rust stains are removed by dipping or spraying the article with a solution containing a bacterium (thiobacillus ferrooxidans WU-66-B or thiobacillus thiooxidans WU-79-A) plus an inorganic salt (iron sulfate or ammonium sulfate) and glucose. This process has been shown to be environmentally acceptable. It is felt that this method could be applicable for those cleaning conditions where citric acid is now being evaluated. However, much development work needs to be done to the biological cleaning competitive or practical, especially for large surfaces.

#### 3.2.13 Protecting Steel Prior to Blast Cleaning

It has been found by the SSPC<sup>(72)</sup> and others<sup>(42)</sup> that structural steel with mill scale that scale has been kept intact prior to blast cleaning is much less prone to rust after blast cleaning and even after painting. This phenomenon is apparently due to the fact that ferrous and

ferric salts, (nitrates, sulfates, chlorides, and other electrolytes) that are formed during storage of steel prior to fabrication are not completely removed by any amount of blast cleaning. In any case, steel rusts in some environments - especially industrial and marine - is subject to flash rusting after blast cleaning and in many instances tends to show premature rust symptoms even after shop priming. This effect can apparently be overcome by certain types of wet blast cleaning which result in removal of soluble salts (See Section 3.2 .2). Another approach is to prevent the salt formation by protecting the steel during storage well enough to retain its mill scale layer relatively intact. Further study is necessary, however, to determine quantitatively the effect of this phenomenon on paint life and the cost effectiveness of alternative methods of preventing or correcting it.

#### 3.2.14 New Abrasive Propulsion Method

Most blast cleaning units use either compressed air or centrifugal force to convey velocity and energy to the blast cleaning particles. Both of these have obvious drawbacks. Air blast requires a large volume of air per pound of abrasive, is limited to relatively low density particles, results in polluting dust clouds, creates excessive noise, limits visibility, requires elaborate safety precautions, and is a slow, painstaking labor-intensive operation. Centrifugal blast cleaning, on the other hand requires expensive bulky equipment; it is not, in spite of excellent recent developments, well adapted to complete portability; and it involves considerable wear and maintenance. Over the years the SSPC has sought other means of propulsion. One of these involves blast cleaning with metallic abrasives propelled magnetically through a linear rotor in the form of a wound hose or helix.

#### 3.2.15 Newel Removal of Mill Scale at the Rollins Mill

Preliminary work by the SSPC indicates that certain relatively simple procedures may be used at the lint-rolling step in steel production to prevent or modify the formation of mill scale, or to remove it economically. In the same sequence, a protection can be applied at

post-rolling temperature which is compatible with the subsequent handling, fabricating, and further coating of the steel.

Further work would be required to explore the practicality and cost effectiveness of altering the sequence of steel protection in this way. Considerable savings potential appears to be possible through retaining the large tonages of steel now lost through mill scale formation, eliminating the considerable cost of again removing such mill scale and cutting the high costs of current labor-intensive methods of applying protective coating system at ambient temperatures during or after fabrication.

#### 3.2.16 Explosives

The detonation of an explosive charge has been used to project abrasive particles such as sand or metal powder onto the surface to **be cleaned<sup>(141)</sup>**. Although this method shows some potential for cleaning the interior of pipes or other confined areas, its impact on the blast cleaning trade will most likely remain insignificant.

#### 3.2.17 Electrolytic Descaling

Electrolytic descaling has been in use by the ship painting industry for some time to prepare the surface of steel structures, such as ballast tanks immersed in sea water<sup>(137)</sup>. A magnesium ribbon with a steel core is welded or clamped to the structure in such a way as to make good electrical contact. Introduction of sea water (an electrolyte) into the tank, completes the electrical circuit and initiates galvanic action. After six or seven days, the tank is drained and washed. This process results in a surface that is about 90% clean. If a high performance coating is to be applied, the remaining contaminants must be removed by abrasive blasting or another suitable method.

#### 3.2.18 Very Fine Non-Metallic Abrasives

Very fine non-metallic abrasives, when used in experimental applications, had a high cleaning rate and the abrasive could be air-borne

away from the cleaning site<sup>(143)</sup> . However, pollution and visibility problems remain.

#### 3.2.19 Cryogenic Coating Removal

A new technique uses liquid nitrogen ( $-196^{\circ}\text{C}$ ) for cryogenic removal of organic coatings. The stream of liquid nitrogen sprayed onto the substrate embrittles the coating; it is then easily removed with recyclable plastic pellets. Additional engineering efforts are underway to improve the versatility and portability of the equipment.

ANNEX A  
Annotated Bibliography and References

APPENDIX -- ANNOTATED BIBLIOGRAPHY AND REFERENCES

ANNOTATED BIBLIOGRAPHY

SURVEY OF EXISTING " & "PROMISING "NEW "METHODS "OF " SURFACE "PREPARATION

1. Allaud, D. , "Technical Aspects of Grit..Blasting with Metallic Particles. Choice of Type of Grit". Superficie "Papers, pp. 3-14, 1976.

A comprehensive survey of blast cleaning with metallic grits is presented covering the action of the particles during cleaning; the choice of grit, in particular its content of foreign matter; the effect of the substrate; the degree of cleaning required; and control of the surface condition. Costs are also considered. (In Italian. )

2. Alonso, A. (Jr.), "Mechanical Preparation of Surfaces by Blast Cleaning with Abrasives". - Pinturas Acabados, Vol. 16, No. 76/19, pp. 58-63, 1975.

General principles are discussed and different abrasives, e.g. Carborundum, glass or metal, compared. (In Spanish. )

3. Anon. , "Blast Cleaning System". Polym. Paint Col. Journal, Vol. 167, pp. 202, 1977.

A method of blasting and washing a metal surface at one pass with an automatic feed of an inhibitor to hold the cleaned surface for 24 hours is described.

4. Anon., "Blasting Material for All Purposes". Oberflaeche, Vol. 17, No. 1, pp. 10-11, 1977.

A table is provided showing type of blasting material, process for using, mode of action, field of use and general cost level. (In German.)

5. Anon. , "Code for Preparation and Pretreatment of Metal Surfaces". Austral. Corros. Eng., Vol. 19, No. 7, pp. 21, 1975.

The contents are indicated of the following parts of an Australian standard code of recommended practice (AS 1627): Part 1—decreasing **of** metal surfaces using solvent or alkaline solutions; Part 4—abrasive blast cleaning of steel surfaces; and Part 9—pictorial surface preparation standards for painting steel surfaces. Reference to subsequent coating is made in Part 4. Parts 1 and 4 supersede AS CK9 Parts 1 and 4 respectively.

6. Anon., "Conversion-Coating in One Operation". Metal Finishing Journal, Vol. 17, No. 201, PP. 260-261, 1971.

Describes a new proprietary wet-blasting technique which provides descaling, decreasing, general cleaning, etching, and phosphating in a single pass. A high-volume stream of liquid-borne solid media, atomized at gunpoint to the desired degree of compressed air, is applied to the contaminated surface. The carrying liquid embodies a standard phosphate solution.

7. Anon. , "Ellco Waterblaster".

Water blast cleaning is a method of surface preparation incorporating a fine stream of water at extreme pressure. Water blasting cannot give a white metal surface with a 1.5 mil profile height but it can perform some jobs better than sand. It will out-perform pneumatic and hand tools in most cases, doing a better job at a lower cost. A very important consideration is that this process can be used in areas where fire or explosion hazards exist. Water blasting will remove almost everything except tightly adhering paint. The resultant surface will not have a uniform appearance as the steel itself is not etched by water as it is with sand. It might be compared to a brush-off abrasive blast cleaning where only loose deposits are removed.

8. Anon., "Impact Finishing: Synthetic Abrasives Erode the Natural. Markets". Ind. Materials, No. 121, pp. 19-21, 23, 25-27, 29, 31, .October 1977.

Legislation, outlining the use of free silica in send blasting forces the development of alternatives. New blasting techniques described include: "vacu-Blast", Wheelabrator, hydroblasting, shot peening, and plastic deflashing. Non-silica abrasives discussed are the metallic. Synthetic and natural aluminum oxide abrasives, slag, glass beads, and natural abrasives are also listed as replacements.

9. Anon., "Mechanical Treatment of Surfaces by Sand and Shot Blasting". Galvano, Vol. 44, pp. 947-52, Dec. 1975.

Dry sand- and shot-blasting are discussed in terms of the following abrasives: alumina (corundum); slag (following prohibition of silica abrasives); peach stones and nut shells; cast iron, steel shot, aluminum and other metallic abrasives; and nylon and glass beads. Grades in use are tabulated by size and type for French and SAE/standards. Liquid techniques using anticorrosion, anti-agglomeration and antifoaming (silicone-based) media with the abrasive are considered. The equipment used is described. (In French). (Also in Section U).

10. Anon, "New Systems for Preparing Ships' Hulls for Painting", Materials Protection, Vol. 12, No. 3, p. 44, 1973.

The new system uses steel shot which is blasted against the hull surface through a hose on a traveling boom. A vacuum recovery unit picks up the used shot and all material removed from the hull, including corrosion, marine growth and old paint. The mixture is routed through a separator where the shot is sent to a holding tank for reuse and the waste material is disposed of without polluting the air or water.

11. Anon. , "Review of Shot Blast Developments". Anti-corros.. Vol.24,6pp. 1977. .

Review of new proprietary equipment is presented.

12. Anon., "Sandblasting Report - Viable Standards Could be Out in ' 79". Prof. Decor. & Coat. Action. p. 6, December, 1978.

Silica Safety Association directors will work with NIOSH and OSHA until abrasive blasting and silica dust standards are issued.

13. Anon., "Shot Blasting Plant: Cleaning of 75 Ton Ship Sections", Shipbuilding International, Vol. 11, pp. 10, 22, 1969.

Short article which describes the dimensions, capacity, and advantages of what is believed to be (in 1969) the world's largest airless blast-cleaning cabinet. It was built for General Dynamics Corporation and is located in Quincy, Massachusetts.

14. Anon., "Synthetic Abrasives Erode The Natural Markets". Ind. Minerals, pp. 19-31,1977.

A review is presented of the various alternative abrasives for blast cleaning, including metallic abrasives, natural aluminum oxide, synthetic abrasives, slag, glass beads, olivine, garnet and sand. Equipment for and uses of this product are outlined.

15. Anon. , "Which Abrasive For Which Surface?" Oberflaeche/JOT, Vol. 17, No. 13, (2 pp.) 1977.

A table surmises the method of use, action, applicability and cost of the various blastcleaning abrasives. (In German)

16. Auboux, J., "Surface Preparation Before Painting." Double Liaison, Vol. 23, No. 256, pp. 40-1, 1976.

Automatic, semi-automatic and traditional blast cleaning methods, shop primers and standards for blast-cleaned steel are briefly described. (In French)

17. Bahlmann, W., "Blasting of Steel Surfaces for Coating: Significance and Testing of Degree of Cleanliness and Roughness." Ind. - Lack. - Betrieb, Vol.45, No. 12, pp. 453-7, 1977.

Photographic, electrical and reflection methods for measuring the cleanliness of blast-cleaned metal surfaces, and methods of detecting oily impurities, moisture and iron salts are described. The effect of the degree of cleaning of the surface on paint durability is demonstrated and instrumental methods for measuring surface roughness are described. (In German)



18. Bahlmann, W., "Mechanical. Surface Preparation. " Ind. - Lack. - Betrieb, Vol. 45, No. 11, PP. 421-6, 1977.

The first part of this paper discusses the blast cleaning of steel surface prior to painting, types of blasting abrasive, and DIN standards for blast cleaned surfaces. (In German)

19. Baldwin, B., "Methods of Dust-Free Abrasive Blast Cleaning". Plant Engineering pp. 116-125, Feb. 16, 1978.

Flying dust and abrasive, masking of plant equipment, and dust cleanup are problems that can be minimized by using abrasive-blasting equipment with integral abrasive and dust collecting systems. This article outlines operating principles and characteristics of portable, dry blasting equipment with integral dust and abrasive recovery systems. For air blasting with airless centrifugal blasting this report includes a description and comparison of equipment plus a discussion of abrasive selection, alternative methods, and typical job applications.

20. Banfo, C., "Grit Blasting in Factories. " Superficie Papers, p. 23-36, 1976.

The various types of blast cleaning plant are described and the relative merits of the mechanical turbine and the compressed air-free, jet processes are compared. Transport of objects to be blast-cleaned and recovery of abrasive are considered, and some typical profiles of blast cleaned surfaces shown. (In Italian).

21. Barbier, S. E. J., "Elimination of Surface Deposits on Metallic Apparatus by Using An Explosive Charge"., France 2, 094, 922, March 10, 1972.

Describes a method of cleaning metal surfaces with deposits of rust or scale using the detonation of an explosive charge to project abrasive particles such as sand, corundum, metal powder, or glass -- onto the surface to be cleaned. The explosive charge can be a detonating fuse, a cartridge of cartridges, or a flat surface. The charge can also be fashioned to conform to the shape of the surface being cleaned.

22. Barillion, P., "Methods Used In Shipyards for Studying Surface Contamination, Residual Scale, and Local Electrochemical Potential of Plated", Working Group on "Surface Conditions" of the Comite International Permanent Pour La Recherche Sur La Preservation Des Matériaux en Milieu Marin.

During ship surface preparation, inspections must be made to insure that blast-cleaning has removed all millscale and salts from the steel surface. The electrochemical potential of the plates should also be monitored because differences in potential over various areas of the steel plate may give rise to corrosion phenomena even when millscale and other contamination have been removed. This report deals with inspection methods for shipyard use and the requirements that must be met by these methods.

23. Barrillom, P., "Preservation of Materials in the Marine Environment—Analysis of Replies To The Enquiry on Methods Of Surface Preparation in Shipyards", 1964.

This report presents a summary of replies by 45 shipyards to an enquiry on the methods of surface preparation currently in use. The O.E.C.D. Group of Experts on the Preservation of Materials in the Marine Environment, in the course of its cooperative research work and in view of its interest in the question of hull surface preparation conducted this survey.

24. Bartolomucci, F., "Qualitative and Quantitative Assessment of Wet Grit Blasting". Superficie, pp. 47-51, 1976.

The wet grit blasting processes with compressed air water jet and pneumatic gun are compared. The effect of treating the surface, after blast cleaning, with corrosion inhibitors prior to painting has been examined. (In Italian).

25. Bendelow, A., "Surface Preparation". 1st Internat. Ship Ptg. and Corros. Conf., pp. 61-6, 1974.

Abrasive blast cleaning for ships is discussed.

26. Bendelow, A., "Surface Preparation: Abrasive Techniques, etc.". Corros. Services in the United Kingdom, pp. 12, 1976.

This account deals with methods of surface preparation, treatment of new steel and steel that has been in service, equipment, expendable abrasives and international standards of surface preparation.

27. Bender-Christensen, B., "An Investigation of a Combined Blasting and Coating Technique: A patented process". Hemple's Marine paints Copenhagen, Denmark, 1976.

Traditionally abrasive blast cleaning and priming of steel surfaces have been considered as two separate processes; however, many obvious advantages and simplifications can occur if these two separate processes are combined. Experimental results of blast cleaning with both metallic and non-metallic abrasives that have been coated with a zinc dust binder mixture are given. "The most pronounced effects, obtained with the zinc coated abrasives in comparison to the untreated abrasives, are seen with paints of low film thickness (0.4 to 0.8 mils), especially zinc-rich primers, where the corrosion resistance is significantly improved. Moreover where the surface has been contaminated by salts, a much higher durability is achieved with zinc coated abrasives."

28. Bennett, P. J., "Current Occupational Safety, Health, and Pollution Codes and Their Effect on Surface Preparation". Paper No. 46, pp. 1-9, 1973.

The paper discusses two primary methods of blast cleaning: dry blast and water blast, and their relation to organizational codes of OSHA, EPA, ANSI, and others. Chart on six (6) blast cleaning tests is included.

29. Bendelow, A., "surface Preparation", Hedge Clemco Ltd.

Presents a summary of various techniques and machines which are currently being used for blast cleaning. Some aspects of air blasting including wet blasting and inhibitors, large capacity blasting machines, abrasives, and abrasive recovery systems, are covered.

30. Birn, J., "Anticorrosive Painting of Bulk Cargo Ships During Their Construction"., Ochrona Przed Korozja, Vol. 14, No. 2, pp. 15-19, 1971, (In Polish).

Shipyard surface preparation and painting practices are discussed. Shot blast cleaning techniques for the cleaning of steel surfaces prior to coating with a zinc dust primer are described. Blast cleaning equipment installations are also dealt with.

31. Bradley, G. W., Martin, L. D., Banks, W. p., and Frost, J. G., "Investigation of Ammonium Citrate Solvents", International Water Conference, Pittsburgh, Pennsylvania, 1975.

The ammonium citrate process is a means of removing both magnetite and copper from boilers and other equipment by using a solution of citric acid. The primary purpose of the reported investigation was to determine the conditions that facilitate optimum copper dissolution and steel passivation using aqueous ammonium citrate solvents. The study involved the determination of the extent of magnetite dissolution, the electrochemical polarization curves for copper and mild steel, the rest potentials for steel, copper, and couples steel-copper electrodes, and the weight loss of copper coupons.

32. Bresle, A., "Corrosion of Steel and Dangerous Chloride." Ind. Fin. Surf. Coatings, Vol. 28, No. 335, p. 15-8, 1976.

Problems in establishing relationships between sulphur and chlorine concentrations in marine or industrial atmospheres and corrosion velocity are discussed, together with the distribution of chlorine in rust. Small amounts of chloride, at least in the case of steel surfaces cleaned by pickling, may initiate rust attack. Reference is made to steel-brushing and sandblasting in connection with the subsequent behavior of painted steel surfaces. In general, the role of chlorides in the atmospheric corrosion of steel is considered to be underestimated. 17 refs.

(Also in Section O).

33. Bresle, A., "Corrosion of Steel and The Danger of Chlorides. " Pinturas Acabados, Vol. 19, No. 91, pp. 71-6, 1977.

The effect of chloride ion on inducing the corrosion of steel and the necessity for adequate removal of chloride by blast cleaning prior to painting are described. (In Spanish with 17 refs.)

34. Bresle, A., "Painting Oxidized Steel: New Approach to an Old Problem." Pinturas Acabados, Vol. 19, No. 91, pp. 31-4, 1977.

New pretreatment for oxidized (rusty) steel prior to painting consists in treatment with a solution of lithium hydroxide in an organic solvent mixture (mainly alcohols). This was superior to washing the surface with the solvent only or water. The process has been patented. (In Spanish)

35. Bresle, A., "Painting Rusty Steel Surfaces: New Look at Old Problem." Ind. Fin. Surf. Coatings, Vol. 28, No. 336/337, p. 4,6, 1976.

Methods are outlined of treating rusty steel to render the rust layer clean and salt-free before painting. Results are reported of salt spray tests on pre-rusted steel panels first treated by one of the following: alcoholic solution of lithium hydroxide, distilled water, alcoholic solvent, and then covered with a conventional rust-inhibiting paint. The lithium hydroxide solution pretreatment gave the best results, greatly improving subsequent corrosion resistance.

36. Brown, C. F., "Intensity and Surface Finish Accomplished with Spherical. Glass Particles", Prismo Safety Corp., Huntington, Pennsylvania, May 20, 1962.

In order to determine the merits and limits of using glass beads in blasting, a series of tests were conducted to study the effects this material had on surface roughness and appearance, erosion or weight loss, and peening. The characteristics of hardness, specific gravity, and sizing of the glass beads were controlled in this study. Data relating the effects to the controlled parameters is reports.

37. Bryant, C. P. W., "Surface preparation." Austral. Corros. Eng., Vol. 20, No. 5, pp. 9-11, 1976.

Various methods used in treating metallic surfaces prior to protective surface coating are listed, with brief comments on the methods and their results. Profile heights, classes or levels of blast cleaning, specification of surface preparation and relevant standards are also referred to.

38. Bullett, T. R., "Preparation and Protective Painting of Structural Steel". Corrosion Prevention and Control, Vol. 18, pp. 8-12, 1971.

Controlling cleanliness and surface profile, for abrasive blast cleaning of steel surfaces, are discussed. An extensive exposure series was made on new and rusty steel blast cleaned with various abrasives and primed with typical primers. The results obtained for the painting of rusty steel underline the difficulties involved with painting this substrate. The main cause of trouble was found to be the formation of corrosion pits carrying ferrous sulphate which, under appropriate conditions, can hydrolyze or give sulfuric acid, causing renewed corrosion. Wet blasting or the use of high pressure water jets appears to be useful in removing most of the salts.

39. Byrd, Jerry D., "Other Ways To Do It". NACE Corrosion '76, paper No. 61, 1976.

Alternates to dry sand blasting are discussed in addition to high solids coatings and water-based coatings.

40. Cain, John, "Abrasive Blasting: Present Problems, Available Safeguards". Sr. Tech. Service Engineer, Occ. Health & Safety Prod. Dept., 3M Company, 1975.

Problems associated with the abrasive blasting process include air contaminants, lack of ventilation, and problems relating to equipment design and maintenance. The protection needed and the equipment available to provide it are discussed, along with the rules and regulations governing equipment use.

41. Cain, J., "Abrasive Blasting--Present Problems, Available Safeguards", Occupational Health and Safety Production Dept., 3M Company.

The most important problems include air contamination (from the abrasive medium being used and from the substances being removed), inadequate ventilation, and poor equipment design and maintenance. The protection needed for workers in abrasive blasting areas, and the types of protection equipment presently available are presented. A short summary of some pertinent OSHA and NIOSH rules and regulations is included.

42. Calabrese, C., and Allen, J. R., "Surface Characterization of Atmospherically Corroded and Blast Cleaned Steel". Corros. (NACE), 34, No. 10, pp. 331-338.

A report on the results of examining industrially corroded steel surfaces as characterized by optical and electron (SEM, EDXA, EPA) microscopy. Sulfur and chlorine contaminated sites were tested.

43. "California State Standards for Sandblasting Operations".

New Subchapter 6 in Chapter 1 of Part III of Title 17 of the California Administrative Code. Includes articles on general provisions, prohibitions, enforcement, visible emission evaluation techniques, and performance standards.

44. Cardiel, J. De E., "Medium-Sized Shipyards and Problems in Surface Preparation". Ingenieria Naval, Vol. 44, pp. 5, 1976.
45. Conn, A. F., and Rudy, S. L., "Parameters for Ship Hull Cleaning Using Cavitating Water Jet Method". Maritime Res. Center Rept., Vol. 32, pp. 129, 1977.
46. Costa, M., "Olivine: Material Less Liable to Cause Silicosis for Use in Blast Cleaning". Riv. del COL, 10, No. 111/112, pp. 237-240, 1977, (in Italian).

Olivine is an amorphous mixture of magnesium silicate and ferrous silicate that has been mined in Italy since 1966. Its chemical composition and characteristics are detailed. When substituted for foundry grit in blast cleaning, Olivine showed a lower tendency to form dust. Olivine appears to be less liable to cause silicosis than is sand used for blasting.

47. Dannen, Mark, "Abrasives: The Alternatives to Sand". Am. Paint Contr., pp. 18-27, November, 1975.

As the use of silica sand as a blasting abrasives receives increasing criticism, many people are turning to alternate abrasives. This article deals with the sand blasting business in California and how contractors there are coping with the new legislation concerning the use of sand. OSHA and NIOSH recommendations are discussed, and the use of substitutes for sand is observed.

48. Dannen, M. A., "Battle Over Sandblasting Begins". Am. Paint Cont., pp. 14-21, May, 1973.

California's standards for sandblasting receive opposition from industry. Background to the resolutions submitted to California Legislators concerning the new regulations is included.

49. Dasgupta, D., Ross, T. K., "Cleaning of Rusty Steel for Painting". British Corrosion Journal, Vol. 6, No. 6, pp. 237-240, 1971.

A study of the characteristics of the contaminants found in rust that was formed in an industrial atmosphere showed that ferrous sulphate and ferric chloride were present. It was not possible to remove all traces of these contaminants from the steel surfaces by dry abrasive blast cleaning, however, small abrasive particles were more effective in removing these salts from the corrosion pits than larger particles. Combined abrasive and water blasting is more effective in cleaning rusty steel, especially for the removal of salt contaminants. An "in Situ" test developed for detecting residual salts after various degrees of blast-cleaning is based upon a potassium ferrocyanide color change.

50. de Vries, D., "Automatic De-Rusting Equipment for Hull Steel Preparation". Geveke Werktuigbouw, BV, Ch. 7.

This chapter describes a portable closed-cycle centrifugal blast-cleaning machine for ship dock and shipyard use. The details of the machine's construction and operation are discussed.

51. duPont deNemours and Company, "Alternative (Blast Cleaning Abrasive)". duPont Mag., Vol. 71, pp. 24-25, 1977.

A brief description is given of comparative tests between silica - sand and a proprietary blast cleaning abrasive (comprising a blend of coarse and fine grains of staurolite) which demonstrated the technical and economic superiority of the latter.

52. Fong, C., "Pollution-Free Blasting". NPCA 16th Ann. Marine Coatings Conf., 7pp., 1976.

A new surface blasting technique has been developed which utilizes solid carbon dioxide pellets to replace sand or other blasting media. The process provides a method of cleaning surfaces without producing potentially hazardous residues or requiring expensive clean-up operations.

53. Fong, C., "Taking the Sand Out of Blasting". 4th International Environmental and Technical Conference.

The concept of blasting surfaces with some type of volatile pellet was developed at Lockheed-California early in 1969. The idea was to use a pellet composed of a nontoxic material. that would simple sublime--carbon dioxide was settled upon. According to the author, carbon dioxide pellet blasting provides these advantages:

- No debris is produced by the bleating agent that is harmful to either human health or the environment.
- No cleanup of residue is needed.
- The method appears to be widely applicable to the surface-preparation problems of many industries.
- Carbon dioxide pellets can be made readily available at low cost.

54. Geld, I., Deutsch, L., D'Oria, F. J., "A Comparison of Inhibitive Abrasive Blasting Techniques". Materials Protection, Aug., 1968.

A laboratory study of dry, inhibitive abrasive blasting methods showed that a one-stage process with 5% zinc granules in the abrasive was inferior to the two-stage process--abrasive blast-cleaning followed by blasting with zinc shot. However, blasting with an abrasive containing 5% stearic acid was found to be superior to a one or two-stage process employing zinc or aluminum granules. This procedure results in significantly reduced rust formation and can eliminate the need for temporary paint coatings applied immediately after blast-cleaning.

55. Geld, I., Deutsch, L., D'Oria, F. J., "Inhibitive Abrasive Blasting". Conference of National Association of Corrosion Engineers, Proceedings, 24th, pp. 584-586, 1968.

This article is essentially identical to the previously described one.

56. Goodier, J. L., Boudreau, E., Coletta, G., and Lucas, R., "Industrial Health and Safety Criteria for Abrasive Blast Cleaning Operations". Report prepared under contract HSM 99-72-83, Arthur D. Little, Inc., Cambridge, Mass. 02140, 1973.

A survey report on abrasive blast cleaning operations by Arthur D. Little, Inc. encompassing: occupational hazards, protective regulations, and operating procedures abrasive blasting; existing safety and health standards for abrasive blast cleaning, and ventilation and dust removal.



57. Grey, C. A., Hill, L. A., and Marson, F., "Preconstruction Primers". JOCCA, Vol. 59, No. 1, Pp. 22-28, 1976.

In the past, steel fabricators and shipbuilders erected structures and built ships with unpainted steel components, so that extensive rusting of the steel occurred during the building period. In recent years, there has been an increasing use of preconstruction or prefabrication primers. The function of these materials is to prevent rusting.

58. Gutman, E. M., Mubinov, D. M., "Mechanochemical Metal Surface Cleaning Before Application of Anticorrosion Coatings". Korrozi. Zashch. Neftegazov. Prom-sti., Vol. 8, pp. 21-23, 1974, (Russian).

A technique is shown for the removal of oxide scale from the surface of steel pipe involving rotary brushing, moistening the pipe surface with an aqueous solution containing phosphoric acid and a surfactant. This process resulted in improved brushing effectiveness, reduced micro-hardness, and improved adhesion of paints.

59. Hempel's Skibstarve-Fabrik A/S, "Cleaning Metal Surfaces for Painting". Dutch 71.17041, Paint and Resin Patents 1972, Vol. 9, No. 9, p. 202, 1972.

Metal surfaces are blast cleaned before painting using a cleaning agent carrying a protective metal which is deposited on the clean surface. For example zinc dust can be cemented to the surface of sand used to clean steel.

60. Hill, J. W., Lee, M. J., Spalding, I. J., "Surface Treatments by Laser". Optics and Laser Technology, Vol. 6, No. 6, Pp. 267-278, 1974.

Surface treatments practicable with multi-kilowatt, continuous laser beams are considered. In particular, the mechanism, parameters, and advantages for the surface hardening of steels, the de-scaling of surfaces, and the bonding of powders to metallic surfaces are discussed. Preliminary tests have shown that scale or other adhering deposits can often be removed by subjecting them to thermal shock or chemical decomposition using a laser beam. Rust on steel has been subjected to laser beams of several kilowatts. The hydrated oxides are changed to a dense hard scale of magnetite. It may prove practicable to carry out such an operation in a reducing atmosphere to produce a readily removable layer of metallic iron.

61. Hirota, N., "Surface Treating Agent for Removing Burnt Paint Film and Rust". Japanese Patent 75:22,970, Mitsubishi Heavy Industries, Ltd.

A solvent consisting of a mixture of chlorinated hydrocarbons, alcohols, fatty acid esters, and glycol ether is used to remove the burnt paint and rust that results from the welding of painted steel. A mixture of hydrochloric, nitric, and phosphoric acids with a binder and penetrant forms a rust protecting layer by reaction with the steel.

62. Horowitz, J., "The Manufacture of Blasting Medium From Slags Resulting During the Smelting of Metal". Fachberichte, 13, No. 12, pp. 1001-1002, 1004-1009, 1975, (in German).

Slags produced in the smelting of Cu, Fe, and Pb ores are suitable for blasting and free of silica hazards. The manufacturing processes such as heat treating and screening are discussed.

63. Hosoda, M., Saiki, N., Nakamura, J., "Sand Blasting with High-Pressure Steam", Japanese Patent 75:33,121, Dai Nippon Toryo Co., Ltd.

A mixture of sand and antirust agents is blasted onto the surface of steel with high pressure steam. The use of steam instead of water jets results in a shortening of the drying time and significant decrease in the amount of rust formation on the surface of the treated steel. The time till visible rust formation after blasting of steel plates was extended from 36 hours for water blasting to 120 hours for the subject process.

64. Howl, A. E., "Surface Preparation as Applied in the Process of Refurbishing Containers: Selection and Use of Abrasive Blast Cleaning Equipment". Anti-Corros., Vol. 23, No. 10, 7 pp., 1976.

Guidelines are provided for the selection and use of shot blasting equipment and abrasives. The relevant standards are quoted. The factors to be considered in setting up a shot-blasting room, including lighting, ventilation and facilities for abrasive recovery, are reviewed.

65. James, D., "Use of Phosphate Coatings in Fight Against Corrosion". Anti-Corros., Vol. 23, No. 7, pp. 3, 7, 1976.

A brief review is presented of phosphating techniques for use on steel, including treatment prior to painting and special methods such as spray gun phosphating and steam phosphating.

66. Jemitus, J., McKelvie, A. N., "The Integration of the Protection Function when Building a Ship". J. Oil Col. Chem. Assn., Vol. 60, No. 6, pp. 222-226, 1977.

This paper explains why good preservation of ship's steel structure can only be obtained by integrating the preservation requirements at the preplanning stage with the overall building procedures. The role played by the initial cleaning and protection of plates and sections is fully described including the requirements of the protective coating with a blast primer. The damage to the initial protection during the unit fabrication and methods for remedying this are described in detail, together with the importance of completing all ancillary welding and burning at this stage. To effect proper integration of the preservation tasks into the overall day-to-day planning of a ship in construction it is necessary that the shipbuilder employ coating experts in both the planning and production departments.

67. Joly, G., "Sandblasting Agent". Ger. 2,030,219: Ger. Pat. Rept., Vol. W, No. 28, p. 2, 1975 (German).

The sandblasting agent consists of shock-produced metal-refining slag granules, at least 75% of which are not larger than 3 mm. The granules have no sharp edges (and therefore flow easily) and, although they may have a high metal contents do not discolour the substrate.

68. Jones, J. N., "Sandblasting Work History Survey". Mtls. Pfm., 15, No. 10, pp. 24-26, (October, 1976).

Statistics are given on the sandblasting activities of 31.5 companies, almost half of them in Louisiana and Texas. Data are given on safety, practices, use of safety devices, time in sandblasting business, tons of sand used, hours per day, and year per man worked, incidence of silicosis, and the length of employment of those reporting silicosis, among others. Attention is paid to the types of metal blasted, whether blasting is done in open or in enclosed spaces, and geographical distribution of respondents. The data indicate that the incidence of silicosis is of a lower order (0.33% of 6429 workers in 1974), and that better safety controls are in order in some companies both for men actually doing the work and others in areas near sandblasting.

69. Keane, J. D., "Surface Preparation, New Trends in Anti-Corrosion Coatings", International Congress, Milan, 1970.

This report is a summary of surface preparation work of the Steel Structures Painting Council and was presented as the surface preparation summation at the International Congress on "New Trends in Anti-Corrosion Paints" in Milan, October, 1970. The section on surface profile (pages 21-25) summarizes major work done on profile through 1970, including peak-to-valley measurement, microsectioning, scanning electron microscope, depth gauges, valley volume, surface analyzers, pneumatic gauges, comparators, and paint loss in profile.

70. Keane, J. D., Bruno, J. A., "Surface Preparation Versus Durability". Steel Structures Painting Council, February, 1966.

A test was undertaken to compare the performance of paint applied over various common degrees of surface preparation. Included among these were pickling, nine degrees of centrifugal shot blasting, three degrees of sand blasting and three degrees of wire brushing. After 26 months exposure to humid atmosphere, alternate water immersion and continuous water immersion, it was concluded that pickling is better than, or equivalent to, many grades of shot and sand blasted surfaces. There was little difference between performance on white metal and commercial blast cleaned surfaces. Sand blasting was as good as, or better than, the equivalent degrees of shot blasting. For water immersion, wire brushing and solvent-cleaning are much poorer surface preparations than blast cleaning or pickling. Standard SSPC vinyls performed much better than phenolics over all surfaces.

71. Keane, J. D., "Protective Coatings for Highway Structural Steel". Literature Survey, NCHRP Report No. 74A (278 pages), 1969.

An indexed and annotated bibliography on surface preparation, costs, etc. of painting structural steel.

72. Keane, J. D., Bruno, J. A., Weavers R. E. F. "Surface Profile for Anti-Corrosion Paints". SSPC, (October 25, 1976).

This report describes the new concepts developed to date in an intensive study of surface preparation profile and the practical implications for steel surface preparation and painting practices.

73. Keane, J. D., Donatelli, P., "Surface Profile for Anti-Corrosive Painting of Structural Steel, A State-of-the-Art Literature Review". SSPC, October 1, 1974.

This is a literature review of the state-of-the-art for interpreting surface profile contours of blast-cleaned structural steel and how these contours affect the paint performance.

74. Keane, J. D., "Water Blast Cleaning". SSPC Quarterly Report - July 1 Through September 30, 1967.

Describes a demonstration of water blast cleaning observed at the George Washington Bridge.

75. Keane, J. D., "Zinc Shot Blasting of Structural Steel". SSPC (April, 1964).

This report discusses the results of a feasibility study carried out by the Steel Structures Painting Council on a novel method for the temporary protection of steel. This proposed method consists of depositing small quantities of metallic zinc (or other metals) onto bare metal surfaces by shot blasting or by other abrasive cleaning procedures.

76. "KUE: System 9-18". Polymers, Paint, and Colour Journal, p. 202, March 9, 1977.

This system is a method of blasting and washing the surface at one pass, the addition of an automatic feed of an accepted inhibitor provides a system which will clean surfaces to Near-White or White Metal and hold that condition for up to 24 hours. The company has developed a special rig which is completely self-contained and able to drive to the "site".

77. Lamb, R. W., "Abrasive or Sand Blast Apparatus and Method". US 3,994,097: Off. Gaz., Vol. 952, No. 5, p. 1927, 1976.

An apparatus for wet abrasive blasting is described.

78. Lindman, E. K., "preparation and Painting of Ship's Hulls. Health Hazards, Fire and Explosive Risks: A Compilation of Literature and Other Experiences". Swedish Corros; Institute Rept., No. 1977:4, pp. 43, 1977.

Health hazards, fire and explosive risks arising during the preparation and painting of ships' hulls are reviewed, including those arising from sandblasting, burning and welding of primed steel, and handling and application of paints.

79. Maass, W. B., "Sandblasting as a Prerequisite to the Painting of Steel". Metal Finish., pp. 60-62, July, 1969.

An overview of sandblasting is presented.

80. MacGregor, I. R., "Trend Towards 'Press Button' Blasting". Anti-Corros., vol. 23, No. 10, pp. 15-16, 1976.

Some recent developments in blast-cleaning equipment are described.

81. Mallory, A. W., "Centrifugal Blast Cleaning of Surfaces for Painting". Materials Performance, Vol. 16, No. 2, pp. 11-17, 1977.

Surface preparation methods for steel are summarized and justification for proper surface preparation prior to coating presented. Criteria are given to determine the degree of cleaning achieved and various considerations involved in selecting an abrasive cleaning method are discussed. Characteristics of stationary systems for centrifugal abrasive cleaning of structural steel are given and installations illustrated. Application of air and airless blasting methods to ship decks and hulls in drydock and elsewhere is discussed. Portable airless blasting machines for ship surface preparation are described and results achieved evaluated.

82. McKelvie, A. N., "Monitoring Cleanliness and Profile of Blast Cleaned Steel". Materials Performance, pp. 9-11, 1974.

Methods of making quantitative assessments of the degree of cleanliness and the type and depth of profile in steel surface preparation are discussed. Blast cleaning with various low silica content abrasives is also discussed. The work on which this article is based formed part of the research program of the Paint Research Association, Teddington, England.

83. Montuschi, M., "Automatic Grit Blasting of Sheet, Tubes and Industrial Objects". Superficie Papers, pp. 37-45, 1976.

Type of plant and its choice are discussed, and the influence of the quality of the grit, the duration of blasting and the sizes of grit in the working mixture is considered.

84. Murphy, J., "The Starblast Alternative". duPont Meg., July-Aug. , 1977.

A new abrasive has emerged to challenge the traditional sand media. Starblast is a blend of coarse and fine grains of staurolite from a mineral deposit located in Florida. The article recounts a comparison test between sand and Starblast cleaning. Starblast saved time and money over sandblasting. It does a better metal cleaning job in less time using a smaller volume of abrasive material.

85. NACE Recommended Practice, "Surface Preparation of Steel and Other Hard Materials by Water Blasting Prior to Coating or Re-crating". Materials Protection and Performance, Vol. 11, No. 4, 1972.

There are instances when abrasive blast-cleaning is not feasible because the resultant flying abrasive particles and drifting dust could cause harmful or undesirable environmental contamination to near-by areas. In those instances, water blasting is an alternative which may provide an adequate degree of cleaning. Unlike abrasive blast-cleaning, water blast-cleaning has no etching effect on steel or other hard surfaces and therefore is recommended primarily in maintenance painting programs.

86. Neumann, G., "Improvement of Economics and Increased Efficiency in Compressed Air Abrasive Blasting Plant for Derusting and Descaling It". Korrosion, Vol. 3, No. 3, pp. 124-140, 1977.

View is presented of abrasive blasting apparatus and operating conditions, types of abrasives, recycling, theory of the blasting process and costs.

87. Oxy Metal Industrial Corp., "Tannin-Containing Compositions". US 3,975,214: Off Gaz, Vol. 949, No. 3, P. 1093, 1976.

In a pre-paint process for improving the corrosion resistance of steel or zinc surfaces by treatment with aqueous acidic zinc phosphate solution the improvement comprises contacting the phosphatised surfaces with an aqueous chromium-free solution consisting of a vegetable tannin in a concentration of 0.1-10 g./l. and having a pH of less than 6 and above a value which will cause degradation of the coating.

88. Parizino, D. A., "The Use of Low Density Abrasives for Mechanical Surface Preparation". Metal Finish., 73, No. 10, pp. 41-43, 45, 1975.

A new manufacturing technology has developed an abrasive media known as low density or three-dimensional abrasives which are used in intermediate operating. The abrasive particles are impregnated in a synthetic fiber web which is used to produce a variety of brush and wheel products. An advantage of this construction is the web's ability to follow over contours and to clean without changing the geometry of the surface. Factors governing performance of a wheel or brush with this abrasive media include rotational speed, work pressures, lubricants, product grade, and density.

89. "Partek Abras-I-Jector". Partek Corporation of Houston, 1977.

The Partek "abras-i-jector" is a water/abrasive blast system that is an alternative to sand. The advantages of this method are described in this advertising brochure.

90. Pearson, W. W., "Surface Preparation Specification". NPCA 17th Ann. Marine Conf. Paper, 1977.

The importance of developing a good surface preparation specification choice is then discussed of who should write the engineering survey determining the scope of the project and the degree of cleanliness required. Items are then described which must be considered in the specific instance of writing a specification for preparing a carbon steel surface, by abrasive blasting, for the acceptance of a coating.

91. Pedrazzini, C., "Surface Conversion Treatments Before Application of Organic Anticorrosive Coatings". Ind. Vernice, Vol. 31, No. 6, pp. 2.21, 1977.

The traditional phosphating and chromating processes are described as well as a new organic conversion process based on a high MW gallic acid derivative in the form of a glucoside. Test results are reported for steel specimens (as such or blast cleaned) phosphate or treated with the organic process, in a corrosion cabinet or on natural exposure. Optimum results are obtained by blast cleaning to white metal followed by organic conversion treatment. The significance of the results with regard to high-build paint systems is discussed.

92. Pezzoni, A., "Grit Blasting in Shipyards". Superficie Papers, pp. 15-21, 1976.

Particular features are considered of blast cleaning in shipyards. The operation may be carried out in tunnels, booths, or on open sites. Dry and wet blast cleaning processes are compared and blast cleaning is considered in relation to the complete finishing process.

93. Reardon, J. E., "New Developments in the Shipyard". Corros. Coatings S. Africa, Vol. 3, No. 1, p. 39, 1976.

In order to assist in the construction of hull sections, a Belfast shipyard has constructed a painting hall which permits the undercover surface preparation and painting of very large units. The shot-blasting and abrasive recovery facilities are described, together with the airless spray system for applying the paint and the service arrangements.

94. Rillig, O., and Tetens, B., "Blast Cleaning with Various Blasting Materials, II". Ind.-Lack.-Betrieb, Vol. 45, No. 1, pp. 20-26, 1977, (in German).

In this second part, the hygroscopic properties of the blasting materials, their hardness, the darkening of the substrate caused, their bulking volume and sieve analysis are compared. Blasting trials have been carried out relating blasting capacity (sq. m./hr.) and amount of blasting material (kg. persq. m. of blasted surface and per minute of blasting time). The amount of metal removed per kg. of blasting agent and the dust formation have been measured. Profiles of the substrates after blasting and photomicrographs are shown.

95. Rilling, O., Tetens, B., "Blast Cleaning with Various Blasting Materials". Industrie-Lackier-Betrieb, Vol. 44, No. 12, 1976, (in German),

Eleven blasting materials comprising sands, natural minerals, and blast furnace slags were analyzed to determine the free silica content and to detect the presence of toxicologically hazardous components. In addition to particle size breakdown analysis during blasting, the flow properties and hygroscopic properties of the abrasives were examined.

96. Roebuck, A. H., "Safe Chemical Cleaning". NACE Corrosion/78, Paper No. 206, 1978.

Chemical cleaning processes have recently received much attention in the light of pending regulations involving blast cleaning methods. The advantages and disadvantages of several different cleaning agents are discussed, including thylene diaminetetraacetic acid, citric acid, hydroxyacetic acid, sulfamic acid, gluconic acid, oxalic acid, and formic acid.

97. Sandford, J. E., "Zinc Coating Blasted on Steel". Iron Age, August 1, 1973.

A new shotblasting process can weatherproof structural steel for as long as four months prior to painting. First, mill-scale is removed by blast cleaning the steel with an abrasive then the same or similar tandem blast cleaning equipment can hurl zinc powder onto the cleaned surface. This results in a very thin, rust suppressing zinc primer.



98. Sandwith, C. J., Briewick, T., "High Velocity Ice Particles for Cleaning Ship Hulls - A Feasibility Study". 4th International Congress of Marine Corrosion and Fouling, May, 1976.

The tests conducted on a ship hull have revealed that both crushed ice and solid ice can remove fouling and paint from a ship and clean the surface down to bare metal. In addition these high-velocity ice particles have a significant advantage over steel shot and copper slag in that they remove a greater mass of biofouling per impact. The energy required for tested ice particles to remove fouling from a given area is approximately 2/3 of the energy required for copper slag and about 1/2 that required for steel shot. However, the energy required for the ice particles to remove paint from a given area is approximately one to two times the energy required for copper slag or steel shot, but ice leaves no pockmarks, as does steel shot, that can adversely affect the longevity of some paints.

99. Shepard, A. P., "Blast Abrasives". Metro News, Vol. 6, No. 2.

This article discusses some of the inherent characteristics of blast cleaning abrasives which should be considered in connection with different classes of work. The abrasives considered are: natural silica sand, crushed quartz or granite, crushed flint or chat, crushed slag, aluminum oxide, and angular steel grit.

100. Siemens, A., "Apparatus for Cleaning Part of Nuclear Power Plants Wetted by Water During Operation". Austrian 332, 497, September 27, 1976, Ger. Appl. 2,259,345, December 4, 1972, Addn. to Austrian 326,785.

Uses the principle of sand blasting technique with boron oxide particles. The residual blast cleaning material is dissolved and removed by rinse water.

101. Singleton, D. W., "Blast Cleaning in Inflammable Atmospheres". Journal Oil Color Chemists Association, Vol. 59, No. 10, pp. 363-368, 1976.

Sparks are generated during the grit blasting of rusty steel, and this paper first investigates whether these sparks are capable of igniting inflammable liquids or gases of the type which might be present on the deck of a laden tanker. The results indicate that while the sparks produced are numerous, they are dull and on no occasion have they ignited inflammable gas mixtures. It is concluded that grit blasting can be employed successfully on board vessels while they are at sea, provided that all normal safety precautions, and some additional ones given in this paper, are taken.

- 1.02. Sline, L. L., "Abrasive Blasting's Future Called Bleak". JPDCA, pp. 18-19, January, 1978.

The author discusses how the blasting industry could be hung for its sins of the past, unless regulatory agencies appreciate managements good intentions and the effectiveness of modern protective equipment.

103. Smith, R. E., "Evaluation of Sand Blasting for Hardness and Resistance to Dust Generation". Department of Transportation, Division of Highways - Transportation Laboratory Memorandum, September 6, 1974.

This report describes a blasting test developed to evaluate the resistance of an abrasive to the generation of dust. Three similar sands at three different size ranges were tested. The results of particle size breakdown indicated that the greatest factor affecting dust generation for these sands is the initial sizing of the abrasive.

104. Spencer, L. F., "Abrasive Blasting". Metal Finishing Guidebook and Directory, pp. 61-70, 1977.

Abrasive blasting, both wet and dry, is discussed with reference to its uses, equipment (both mechanical and air blast), abrasives, technique and nozzle materials.

105. Spring, S., "Chemicals Used in Industrial Cleaning". Metal Finishing, Vol. 72, No. 12, 1974.

This article describes some of the advantages and disadvantages of specific types of chemicals used in the cleaning of metal surfaces including surfactants, detergents, wetting agents, emulsifiers, and organic solvents.

106. Stevenson, M. R., "Pretreatment and Primers". Australian Corros.Engng., 19, No. 8, pp. 9-10, August, 1975.

The effects of surface preparation and surface roughness on coating performance and thickness are discussed. A brief review of surface reactions in terms of how they affect the substrate-primer interface is given. Anodic passivation, cathodic protection and protection by inert pigments are discussed. A few practical aspects of the use and application of primers are presented.

107. Svoboda, M., Klicova, H., and Knappek, B "Influence of Content of Water-Soluble Chlorides and Sulphates in Zinc Chromate on Corrosion Protection of Steel". Farbe Lack, 83, No. 12, pp. 1083-1087, 1977, in German.

The effects of chloride ion and sulphate ion on zinc chromate pigmented (40%) alkyd paints were examined for atmospheric and water immersion environments. At low concentrations these ions did not adversely affect two coat systems.

108. Textar, Inc. , "Grit Blasting Machine and Method". US 3,981,104, Vol. 950, No. 3, pp. 901-902, 1976.

A machine for removing surface scale is described. It moves over a surface, blasting it with metal grit susceptible to magnetic attraction and, when the relevant part of the machine reaches the position, picks up the used grit from the surface using an endless belt formed from non-magnetic, magnetically-permeable material. Magnetic means attract the grit to the belt and hold it there until the grit is released in a specific region of the machine.

109. Ticker, A., and Rodgers, S., "Abatement of Pollution Caused by Abrasive Blasting: Status in Naval Shipyards". NSRDC Report #4549, 79 pp., 1975.

The current status of abrasive blast pollution abatement efforts in United States naval shipyards is described. Indications are that, with the exception of Long Beach Naval Shipyard, most shipyards have not altered their standard abrasive blasting practices and have had no problems with environmental control agencies. Numerous pollution abatement procedures, tests and equipment are described, and pros and cons for each are discussed. A brief review of legislation leading up to the Navy's Pollution Abatement Program is also included.

110. Usami, S., Kozu, H., "Microbial Surface Treatment of Metals". Ger. Offen. 2,409,649, September 19, 1974, Japan Appl. 23,749, March 1, 1973.

Rust, scale, and stains were economically removed from metal surfaces without causing skin diseases or environmental pollution by treating the surface with cultures of the chemotropic *Ferrobacillus ferrooxidans* ATCC 13,661 or *Ferrobacillus sulfooxidans* ATCC 14,119 at 25-35°C.

111. Usami, S., Kozu, H., "Purification of Metal Surfaces by Microorganisms". Ger. Offen. 2,255,640, May 24, 1973, Japan. Appl. 91,657, November 16, 1971.

Rust and other stains were removed from steel, iron alloys, and zinc surfaces by treatment with a culture suspension of *Thiobacillus ferrooxidans* WU-66B or *T. thiooxidans* WU-79A.

112. Vag-Fos, Ltd., "Abrasive Phosphating of Metals". Ger. 2,407,244, Vol. 13, No. 1, p. 24, 1976.

A phosphating pretreatment for metal surfaces is described in which the metal is bombarded with a stream of abrasive particles such as alumina in an acid dispersion of a zinc, iron, manganese or lead phosphate, impelled at a rate of between 20 and 100 ft./sec. the speed being critical.

113. Wallis, G., "Phosphating - A New Approach". Industrial Finishing and Surface Coatings, Vol. 27, No. 326, pp. 5-6, 1975.

The development of a new phosphating system, which uses an abrasive blasting slurry as the phosphating mixture. A centrifugal separator is used to provide a choice between the flow of blasting particles and the liquids. The basic theory and application of this new process is described.

114. Wheelabrator-Frye Corporation, "Performance Controls Economy in Blast Cleaning Abrasives".

The economy and performance of blast cleaning operations is primarily a function of the abrasives used. To attain maximum economy and efficiency, it is important to select the proper size and type of abrasive for each job. To be truly efficient, an abrasive must clean rapidly, yield a high quality finish, and do this at minimum operation cost. The characteristics of abrasive breakdown, hardness, and size are discussed in relationship to the above criterion.

115. Wilson, R. W. and Zonsveld, J. J., "The Surface Preparation and Protection of Ship Plate". North East Coast Inst. of Engineers and Shipbuilders Trans., 78, pp. 277-324, (1962).

Quality control methods for assessing the extent of rust removal and the height of roughness peaks are described. Techniques are discussed for obtaining replicas of ship plate which can then be examined by microscope. The highest peak-to-adjacent valley value was obtained from the Talysurf traces. Other factors discussed include detection of embedded abrasives, "folded-in" rust and millscale, depth and work hardening, and loose rust. Larger particle size was recommended for cleaning of ship plate, including a high proportion of fine material if rust in pits is to be removed. Neither shot nor grit were believed to present any serious problems in embedding, although individual microsections did show such embedding. Other factors, such as coating composition, weldability, and production not directly related to surface profile, are also discussed.

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117. Steel Structures Painting Manual, Volume 1, "Good Painting Practice". Steel Structures Painting Council, Pittsburgh, Pennsylvania.

#### Chapters From Revision of Volume 1 (See Refs. 118 through 124)

118. Mallory, A. W., Centrifugal Blast Cleaning.
119. Borch, E. and Cheshier, H. S., Metallic Abrasives.

120. Bennett, J., Air Blast Cleaning.
121. Bennett, J., Hydroblast Cleaning and Special Processes.
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123. Spring, S., Chemical Cleaning.
124. Bloodgood, D. T., The Painting of Steel Vessels for Salt Water Service.
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127. Anon., "Bright Ideas -- Xenon Lamp's Intense Flash Burns Off Steel Truss Rust". ENR, p. 11, May 31, 1979.
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133. National Maritime Research Center, Report #NMRC-275-42210-RI
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135. Applcman, B., Federal Highway Administration, private Commmication.
136. Anderson, R. K., "Scotch-Brite Brand 3-Dimensional Abrasive Cleaning and Surface Conditioning on High-Speed Coil Lines", Minnesota Mining and Manufacturing Company, 1977.
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138. Keane, J. D., Bruno, J. A., Weaver, R. E. F., "Performance of Alternate Coatings in the Environment (PACE)", Steel Structures Painting Council, August, 1979.
139. Keane, J. D., "Protection of Structural Steel Work - Some U. S. Experience and Practice". ICE, London, 1979.
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141. Kelsall, T., KUE<sub>s</sub> Ltd. , Private Communication.
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# **ANNEX B**

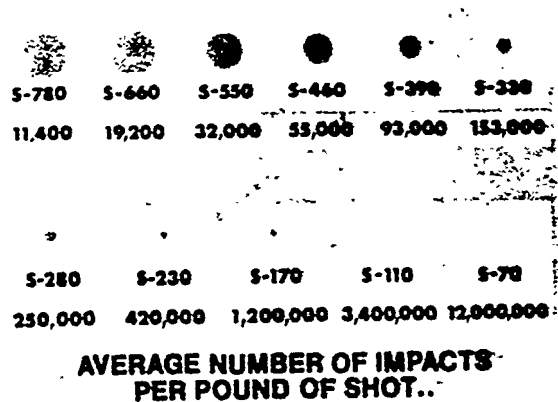
## **Abrasive Blasting Media**

## Annex B

### Abrasive Blasting Media

#### The Metallic Abrasives

An important aspect in achieving maximum performance from an airless centrifugal wheel blaster is choosing the proper abrasive for the job. Consideration must be given to the rate of cleaning, the finish produced, and the rest. These factors are governed by the abrasive's breakdown characteristics, hardness, and size. Abrasives which break down prematurely increase costs of materials. If abrasives are too soft they will not clean as well, and if they are too hard excessive wear and tear on the equipment results. Hardness also affects the rebound properties of the abrasive thereby governing the effective cleaning of cavities and recesses. Abrasive size determines the surface profile height and the speed of cleaning. Use of larger abrasives obviously results in higher profiles. Smaller size abrasives clean faster because of the increased number of impacts per pound of shot (Figure B.1).



**FIGURE B.1:** Average number of impacts per pound of new unbroken shot used to illustrate the need for small, as well as large pellets in an <<operating mix>> in order to achieve full coverage of the surface to be cleaned.



However, **small abrasive** particles deliver *much less impact than the* larger particles **and** therefore may not be able to crack the mill scale some of the larger steel members. For example, **S330 has three times more impact than S230 and five times more than S170<sup>(119)</sup>**. This is one justification for maintaining a properly balanced working mix.

**Table V** gives a list of various metallic abrasives. Although the cast steel abrasives have captured the bulk of the market, others have their special applications. Among the non-ferrous abrasives, zinc shot seems to show the most promise<sup>(75)</sup>. Its properties, particularly Cathodic protection, are more fully discussed in Section 3.2.4.

Table V  
METALLIC ABRASIVES

Chilled Cast Iron  
cast steel  
Malleable Iron  
Crushed Steel  
Cut Steel Wire Aluminum Shot  
Brass Shot  
Copper shot  
Zinc shot

The specific choice on whether to use shot or grit, what size, hardness, etc., must be worked out by the plant engineer through consultation with technical experts from the abrasive companies and through field trials. The concepts briefly discussed here are to serve merely as guidespots. More detailed information can be found in the cited literature<sup>(70, 72, 114, 116)</sup> in trade and technical journals, and in proprietary publications.

### Use of Non-Metallic Blast Media

Except for shop blasting with centrifugal wheel machines, almost all blast cleaning operations use mineral abrasives or other non-metallics. Non-metallic abrasives can be used in both indoor and outdoor operations under varied humidity conditions. Because these abrasives have a much greater breakdown rate than the metallic abrasives, the surfaces of the steel should be checked for dust after blasting; it may need to be brushed off, or shot with a stream of air. Also, because of the dust produced when blasting, this method is generally applied where the flying particles and dust will not have harmful effects on nearby people or machinery.

Operators working near the blast operation should follow all safety and environmental regulations.

Blasting with mineral abrasives has traditionally been economical, but many are turning to other methods (such as abrasive-air-water) that eliminate the problem of harmful silica dust.

Table VI shows air supply versus consumption versus nozzle size for a conventional dry abrasive blasting operation.<sup>(120)</sup>

Table VI

<u>NOZZLE ORIFICE</u>	<u>CFM REQUIRED @ 100 PSI</u>	<u>ABRASIVE CONSUMPTION (Per Hour)</u>
3/16"	60 CFM	260 lbs.
1/4"	105 CFM	490 lbs.
5/16"	160 CFM	812 lbs.
3/8"	232 CFM	1152 lbs.
7/16"	315 CFM	1584 lbs.
1/2"	412 CFM	2024 lbs.
5/8"	580 CFM	2518 lbs.
3/4"	840 CFM	3174 lbs.

The estimate of costs of a particular job depends on several factors which are not easily tabulated: local availability of abrasives, condition of the structure to be cleaned, accessibility of the work, and local environmental regulations. These and other factors must be considered in choosing the most economical abrasive cleaning method.

Non-Metallic abrasives can be classified into three categories: naturally occurring abrasives, **by-product abrasives**, and manufactured abrasives.

Naturally occurring sands are the most commonly used abrasives. Silica sand is a good abrasive which cleans both new steel and maintenance repainting work effectively. Non-silica sands, sometimes called "heavy mineral sands", such as magnetite, staurolite, and olivine rutile, are effective in the use of cleaning new steel but not recommended for maintenance care.

Garnet is a "specialty-type" grit which allows cleaning in a closed system. Permitting this tough abrasive to be recycled a number of times. Because of the high cost of garnets, it is generally used for jobs requiring low abrasive consumption.

Zircon and Novacalite also fall into the category of naturally occurring abrasives. In the fine sizes, these abrasives are suitable for smooth fine finish.

By-product abrasives, because of their low cost and availability in bulk, are generally used for cleaning large steel structures. By-product abrasives come from two main sources: metal smelting slags and electric power generating slags. Both types have relatively uniform physical properties important for the efficiency of blast cleaning new, corroded, or painted surfaces.

Other by-product abrasives include walnut shells, rye husks, peach pits, and ground corn cobs. Available in a full range of sizes, these agricultural products are effective in removing contaminants without destroying or altering paint or metal surfaces.

Manufactured Abrasives - Non-metallic abrasives, made - raw material feed stock, can be manufactured specifically for their toughness, hardness, and shape. Example are silicon carbide and aluminum oxides. Manufactured abrasives, although somewhat costly to produce, can be reused up to 20 times because of their durable qualities. The cost of these abrasives is comparable to by-product abrasives.

Other variations of blast media are also effective. Inhibited abrasive blast media such as zinc coated abrasives, significantly improve the corrosion resistance and coating durability<sup>(27)</sup>. Sane zinc blast treatments can weatherproof structural steel for as long as four months prior to painting<sup>97</sup>). Zinc shot blasting, water ice, and CO<sub>2</sub> pellets are discussed more fully in section 3 .

Inert abrasives such as glass beads are effective<sup>(36)</sup> in some gerations and add no foreign matter to the environment.

#### Characteristic Differences and Their Importance

There are numerous factors which cause abrasives to differ. Basically there are four parameters: shape, density, breakdown characteristics, and size. Angular particles are preferable to round particles for the removal of soft contaminants while hard particles are preferred over soft cries for brittle contaminants. THE size of the abrasive particles determine the number of impacts per volume which is related to the cleaning rate.

Because of the various sizes of abrasives available and types of surface contaminants, care must be taken to ensure that the proper abrasive is selected for the preferred surface finish<sup>(99)</sup>.

Abrasive selection cannot be made at random. It must be governed by the cleaning conditions that will be encountered. sane of the important factors which help to determine the abrasive to be used are:

- o Type of metal to be cleaned.

- shape of the part.
- Kind of material to be removed.
- The surface finish desired on the completed part and the coating thickness that is anticipated.
- Loss of abrasive.
- Breakdown rate of abrasive.
- Cost of reclamation of abrasive.
- Hazards associated with use of abrasive.

Table VII displays the various properties of abrasives and a few of their applications<sup>(120)</sup>.

Only the naturally naturally silica sands, flint, and Novaculite with over 90 percent free silica by weight pose a health hazard. Heavy mineral sands have less less 5 percent free silica, while garnet, zircon, metallic slags, alumina, and silicon carbide are essentially devoid of free silica.

Table VII  
ABRASIVE CHARACTERISTICS

<u>ABRASIVE</u>	<u>TYPE</u>	<u>MAJOR COMPONENT</u>	<u>sHAPE</u>	<u>HARDNESS</u>	<u>SPECIFIC GRAVITY</u>	<u>REUSABLE</u>	<u>RECOMMENDED USE</u>
Steel Shot	Metallic	Iron	Round	Hard	7.2	Yes	Peening
Steel Grit	Metallic	Iron	Angular	Hard	7.6	Yes	Metal Etching
Iron Grit	Metallic	Iron	Angular	Hard	7.4	Yes	Metal Etching
Alum. Oxide	Oxide	Aluminum	Angular	Hard	3.8	Yes	Metal Etching
Silicon Carbide	Oxide	Silicon Carbide	Angular	Hard	3.8	Yes	Metal Etching
Garnet	Oxide	Iron-Silica	Irregular	Hard	4.0	Yes	Metal Etching
Mineral Slag	Conglomerate	Iron-Alum-Silica	Irregular	Hard	2.8	Yes	Metal Etching
Flint	Silica	Silica	Sharp	Medium	2.7	Yes	Metal Etching
Sand	Silica	Silica	Irregular	Medium	2.7	No	Metal Etching
Limestone	Oxide	Calcium	Irregular	Soft	2.4	No	Light Cleaning-No Etch
Walnut Shell	Vegetable	Cellulose	Irregular	Soft	1.3	Yes	Light Cleaning-No Etch
Corn Cob Grit	Vegetable	Cellulose	Irregular	Soft	1.2	Yes	Light Cleaning-No Etch
Glass Beads	Oxide	Silica	Round	Medium	2.7	Yes	Light Cleaning-No Etch

## Pollution and the Environment

Environmental protection must also be considered to minimize dust problems and to ensure the reclamation of the spent abrasives. Tests have been conducted that show a direct relationship to particle size breakdown and environment pollution<sup>(103)</sup>. The finer the initial sizing of the abrasive, the more dust.

## Abrasive Cost and Consumption Rate

The number of times an abrasive will cycle through the propelling unit before fracturing determines the amount of abrasive that will be consumed **per** blasting hour. This consumption factor should be considered along with **the** cleaning rate and purchase price, to determine ultimately abrasive cost **and** consumption. Table VIII gives a rough idea of the abrasive consumption **and** production rate of various abrasives<sup>(120)</sup>.

Table VIII  
ABRASIVE CONSUMPTION & PRODUCTION RATES FOR  
VARIOUS NON-METALLIC ABRASIVES

ABRASIVE	ABRASIVE CONSUMPTION	PRODUCTION RATE	COMMENTS
Silica Sand 16/40 Mesh	2.6 lbs./sq.ft.	4.8 sq.ft./min.	1-1/2 Mil Etch. Dusty.
Garnet 36 Grit	3.6 lbs./sq.ft.	3.6 sq.ft./min.	1-1/2 Mil Etch. Very little dust. Reusable.
Aluminum Oxide 36 Grit	3.1 lbs./sq.ft.	4.6 sq.ft./min.	1-1/2 Mil Etch. Very little dust. Reusable.
G-40 Steel Grit	5.5 lbs./sq.ft.	3.1 sq.ft./min.	2-1/2 Mil Etch. No dust. Grey metal. Reusable.
Crushed Flint 12/30 Mesh	3.6 lbs./sq.ft.	2.7 sq.ft./min.	3 Mils. Reusable.
Staurolite 50/100 Mesh	3.1 lbs./sq.ft.	4.9 sq.ft./min.	1/2 Mil Etch. Smooth surface.
Coal Slag 16/40 Mesh	3.2 lbs./sq.ft.	3.8 sq.ft./min.	2-1/2 Mil Etch. Reusable. Imbedding.
Copper Slag	3.1 lbs./sq.ft.	4.4 sq.ft./min.	2 Mil Etch. Reusable. Imbedding.

**ANNEX C**  
**Quality and Paintability of Surface**

## Annex c

### Quality and Paintability of Surfaces

The value of any new or existing method of surface preparation is dependent, of course, upon the quality of the resulting surface in fulfilling its purpose of preparing the steel for application of durable protective coating systems. This annex of the report therefore concerns itself with the quality of surface preparation including:

- o characterizing the surface with regard to texture, mechanism of cleaning, and imbedments;
- o exposure data on the paintability of surfaces prepared by various wet and dry cleaning methods;
- o the effect of degree of cleanliness, abrasive size, profile height, and coating thickness over that profile; and
- o typical specifications and visual references for quality control in surface preparation.

#### Characterization of Surface

##### Surface Texture

Upon examination of many blast cleaned steel surfaces with the scanning electron microscope (SEM) it became clear that the texture of the surface is dependent upon the type of abrasive used. Other investigations revealed that the profile height is primarily dependent on the size of the abrasive and to a lesser extent on the physical properties of the abrasive and substrate. Figure C.1 shows SEM micrograms of surfaces prepared by blasting with various sizes of steel shop, steel grit, and mm-metallic abrasive. The effect of abrasive type and size on surface profile is readily visible here.



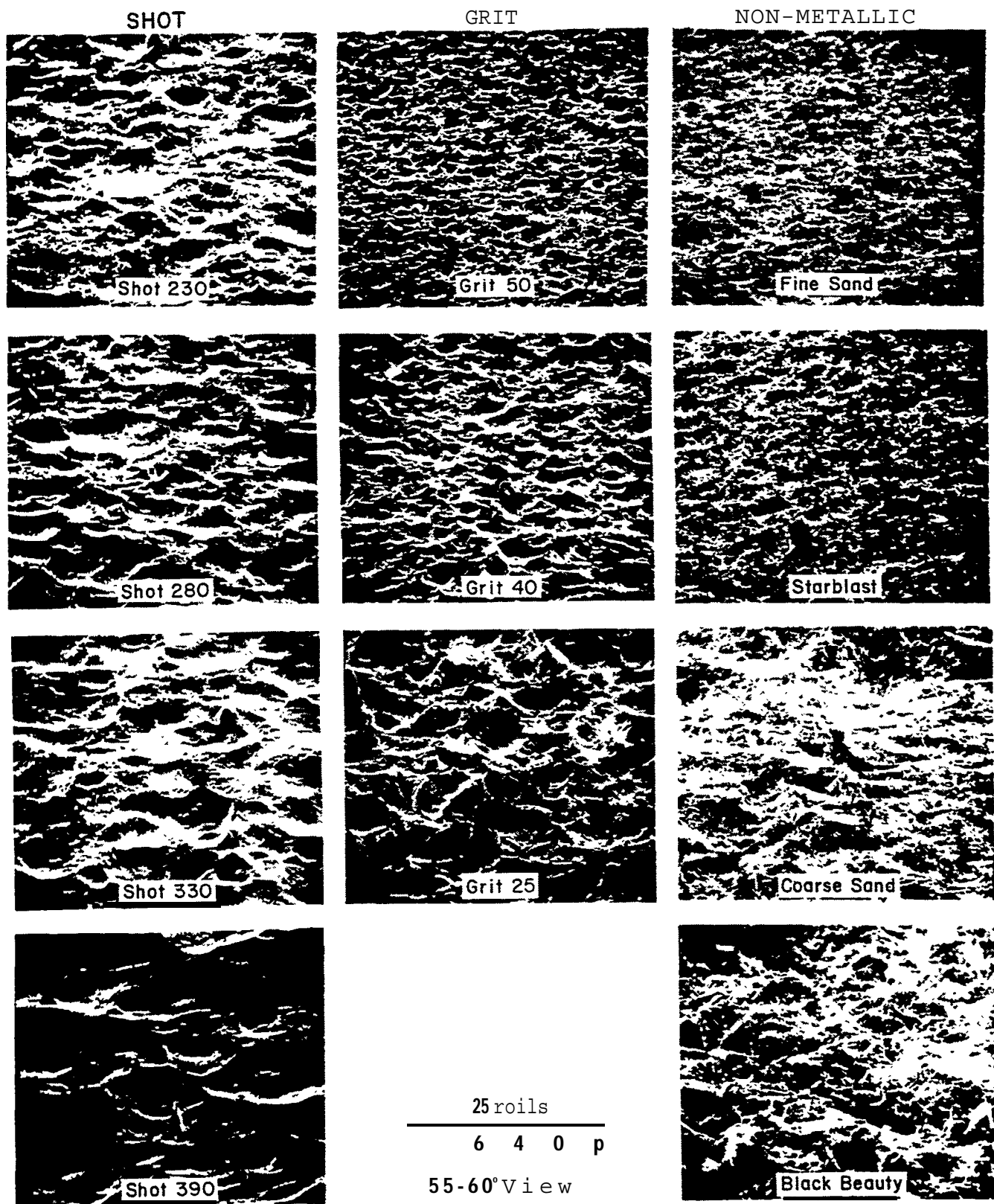
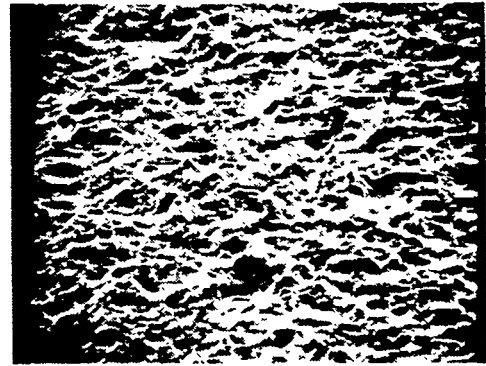
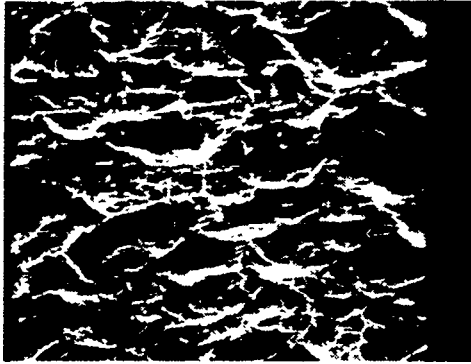


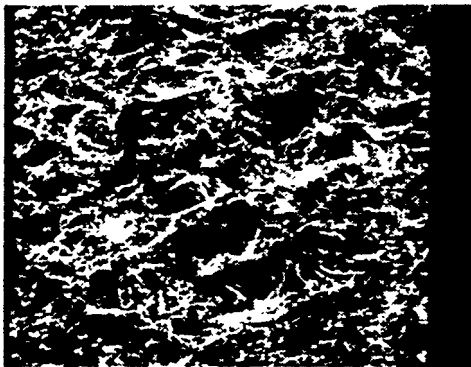
FIGURE C.1: SEM Micrographs Showing Qualitative Features of Some Blast-Cleaned Surfaces (Near White Blast-Cleaned: SSPC-SP10)

TYPE B

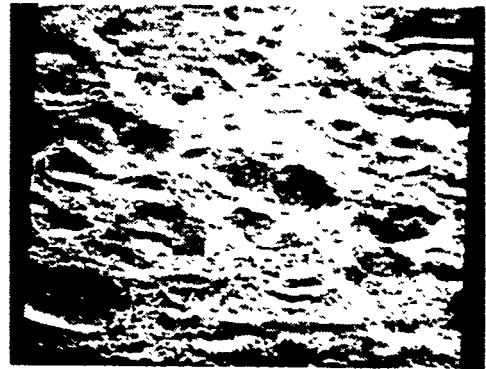


SIMILAR TO TYPE A, WITH MANY WELL DEFINED CRATERS BUT HAVING IRREGULAR SHAPES AND SHARPER PEAKS: GENERALLY PRODUCED BY STEEL GRIT.

TYPE D



VERY IRREGULAR HIGHLY DISTURBED, ALMOST NO SMOOTH CUSPS OR ROUNDED CRATERS, CHOPPY: PRODUCED BY SAND AND SOME OTHER NON-METALLIC ABRASIVES.



HALF THE MILL SCALE REMAINING AND A FINE TYPE C SURFACE WHERE THE MILL SCALE HAS BEEN REMOVED. CHARACTERISTIC OF BRUSH OFF (SP-7) GRADE BLAST CLEANING REGARDLESS OF ABRASIVE TYPE.

TYPE E



VERY SMOOTH. PRODUCED BY PICKLING (SP-8).

SEM MICROGRAPHS

60. VIEW

4mil



IT IS PROPOSED THAT BLAST CLEANED SURFACES CAN BE ADEQUATELY DESCRIBED BY SPECIFYING THE AVERAGE MAXIMUM PEAK/VALLEY ( $h_{max}$ ), THE DEGREE OF CLEANING, AND THE TYPE OF SURFACE TEXTURE.  
FIGURE C.2: Five Categories of Surface Texture

In addition to these three abrasive types, pickling and brush-off blast cleaning give rise to still different types of surfaces. The resulting classification of surface texture into five categories is shown and described in Figure C.2.

Typical surface preparation contours are made visible by the 3-D stereo viewer and film strip. (Viewers and several 3-D film strip are available from SSPC.)

Mechanism of Formation of Surface Features - **Scanning** electron microscopy has uncovered interesting insights into the mode of mill scale removal. During the early stages of metallic blast cleaning, mill scale is found attached at the point of impact while a fracture type surface surrounds each point of shot or grit impact. This mode of scale removal is shown schematically in Figures C.3 and C.4. With non-metallics, on the other hand, SEM evidence indicates a gradual loosening of the mill scale with subsequent chipping off of relatively large pieces.

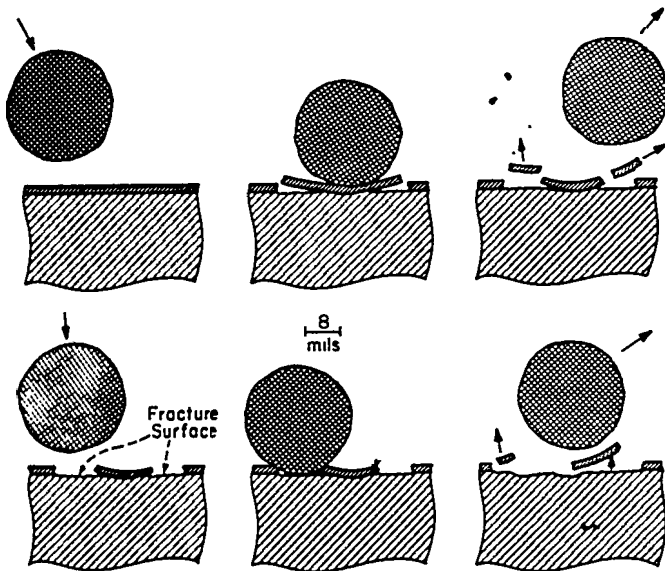


Figure C.3: Schematic of Possible Mode of Mill Scale Removal During Shot Blasting

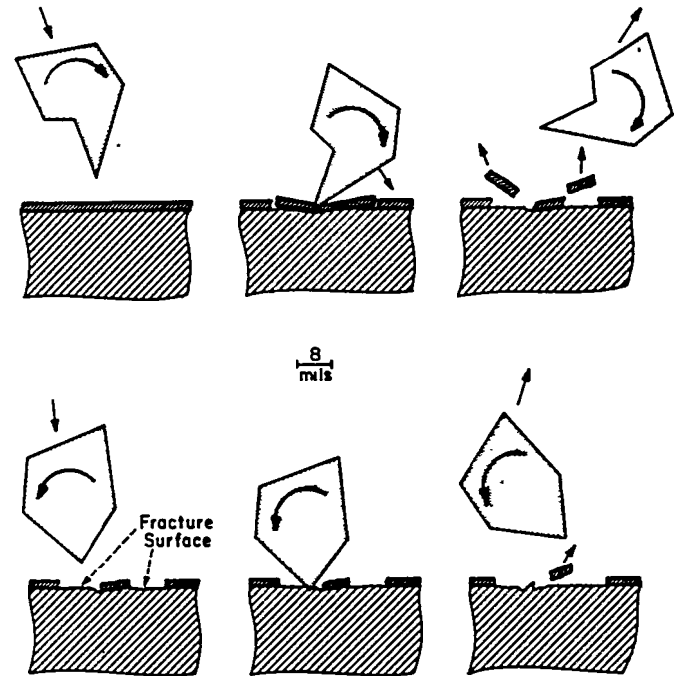


Figure C.4: Schematic of Possible Mode of Mill Scale Removal During Grit Blasting

Imbedded Abrasive - As a class, most non-metallic abrasives produce similar surface textures. It has also been found that non-metallic abrasives leave various amounts of abrasive residue imbedded in the surface. Figure C. 5 shows a possible mode of particle imbedment.

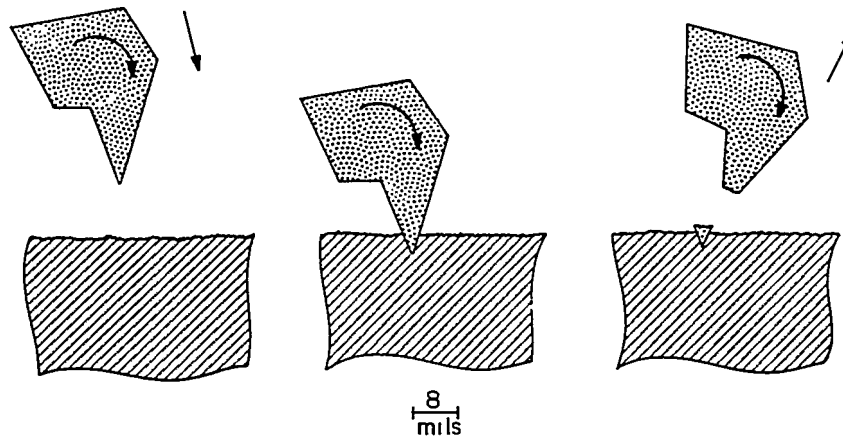


FIGURE C.5: Schematic of Possible Mode of Particle Imbedment

#### Exposure Data on Paintability of Various Surfaces

(1) Mineral Abrasives Versus Shot Versus Grit - Empirical paint tests by the SSPC have shown that, among the commonly used abrasives, there is relatively little difference in the resulting paint performance. No clear superiority has been shown in comparing shot blasted with grit blasted surfaces. However, with a number of paint environment combinations, grit blasted surfaces have resulted in better paint performance than shot, especially in the vicinity of damaged (scribed) areas. Sand blasted surfaces have also shown more resistance to undercurrent at a scribe than shot or grit blasted surfaces, particularly for vinyl systems. These effects may very well be related to the differences in surface textures achieved by the various cleaning mechanism described earlier. The

performance of an alkyd, a vinyl, and a zinc-rich system for various metallic and non-metallic abrasives is shown in Figure C.6 for a salt fog exposure test.

The SSPC has developed a method of comparison whereby the rate of failure is considered along with the time for initial failure to occur. This method, particularly applicable to salt fog data, distinguishes between two paints which have the same exposure time before initial rusting, but which continue to fail at significantly different rates. This "average composite durability rating" is the average of the time it takes a sample to fail to a rust rating of 9, the time to fail to 8, and the time to fail to 7. The 9,8, and 7 refer to the amount of rust on a sample as given in SSPC-Vis 2, where a rating of 10 is perfect.

(2) Wet Abrasive Blasting With and Without Inhibitor -A salt fog test was conducted with alkyd, vinyl, and zinc-rich paints using steel pannels prepared by dry sand blasting, simulated wet sand blasting without an inhibitor, and simulated wet sand blasting with two different inhibitors. The results (Figure C.7 show that under these conditions there is not much difference between wet and dry sand blasting, nor is there much of an effect due to an inhibitor. It must be noticed, however, that these test specimens were prepared from steel plate with clean, intact mill scale. As discussed earlier in Section 3 on wet and novel blast cleaning methods, the most important advantages of wet blast cleaning for marine applications may be, not only dust control, but also the removal of soluble salts from the steel.

As a part of a larger project, SSPC has made plans to use dry and wet blast for steel which has been rusted in several different environments to test the hypthesis that wet blasting, by washing away the soluble salts, provides a better surface for coating with many paint types.

Surfaces Blast Cleaned With Metallic and Non-Metallic Abrasives (SSPC-SP 10)

Each bar represents average of two panels

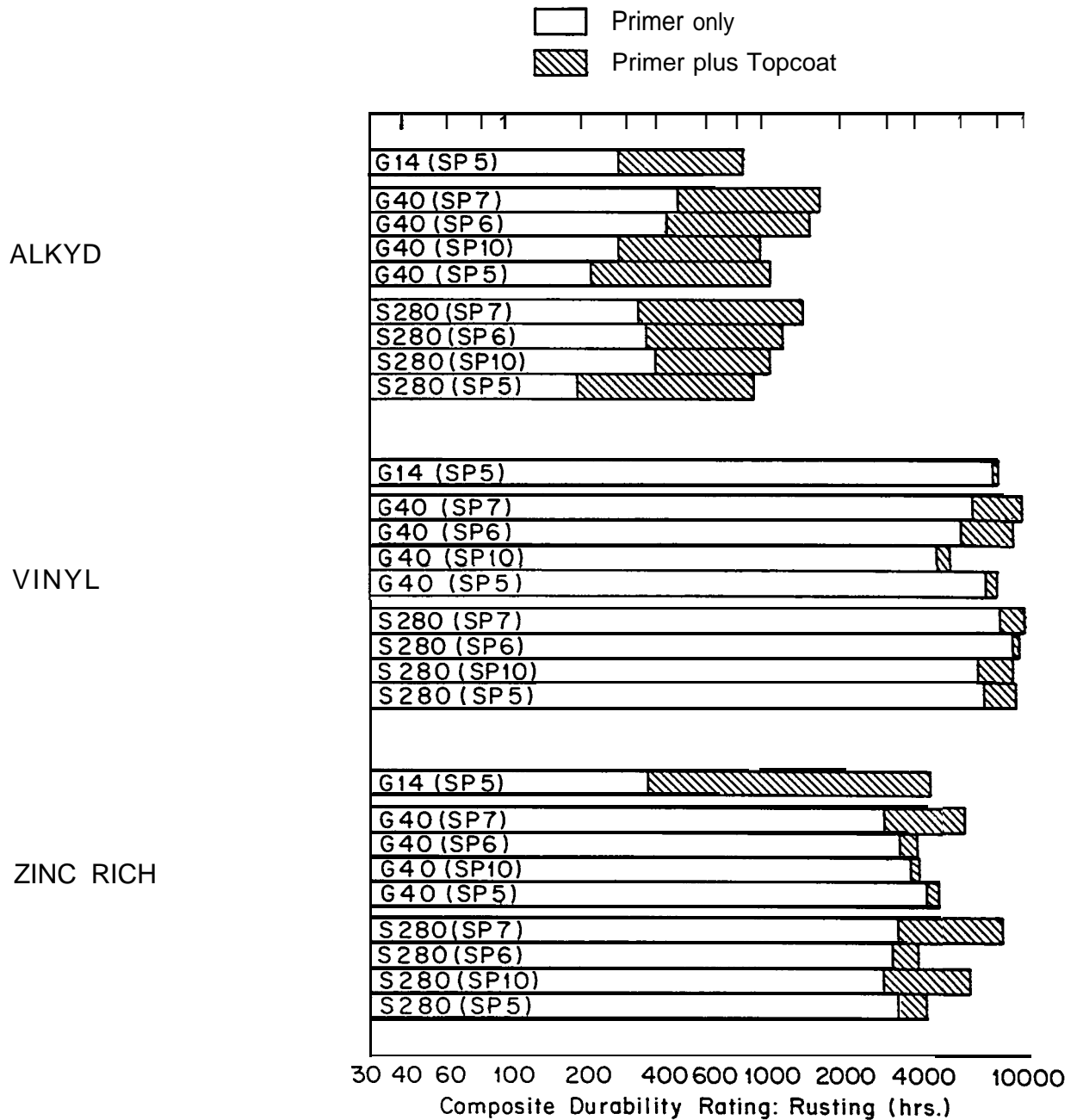


FIGURE C.6: Alternate Surface Preparation Study  
Salt Fog Exposure

Each bar represents average of two panels

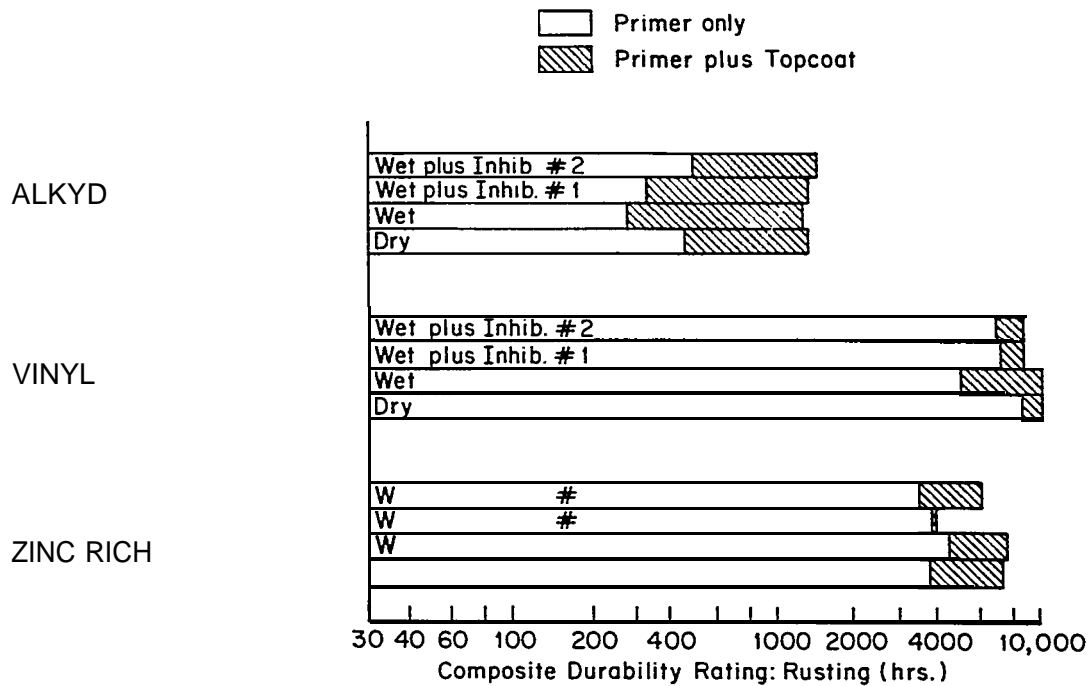


FIGURE C.7: Surfaces Blast Cleaned with Dry Sand & Wet Sand  
 With & Without Inhibitor (SSPC-SP 10)  
 Salt Fog Exposure

(3) Degree of Cleaning - Another set of salt fog data, Figure C.8, shows the effect of the degree of cleaning on paint performance for three generic paints. As can be seen from the data, there is not a very pronounced difference in performance among the various degrees of cleaning nor is there a difference between shot and grit blasting. This result is somewhat contrary to field experience which favors the more thorough degrees of cleaning. This discrepancy can be reconciled when one considers that, unlike panel test conditions, most often in the field one does not usually encounter clean, non-rusted, intact mill scale.

# ALTERNATE SURFACE PREPARATION STUDY

## SALT FOG EXPOSURE

Surfaces Blast Cleaned with Metallic and Non-Metallic Abrasives(SSPC-SP10)

Each bar represents average of 2 panels

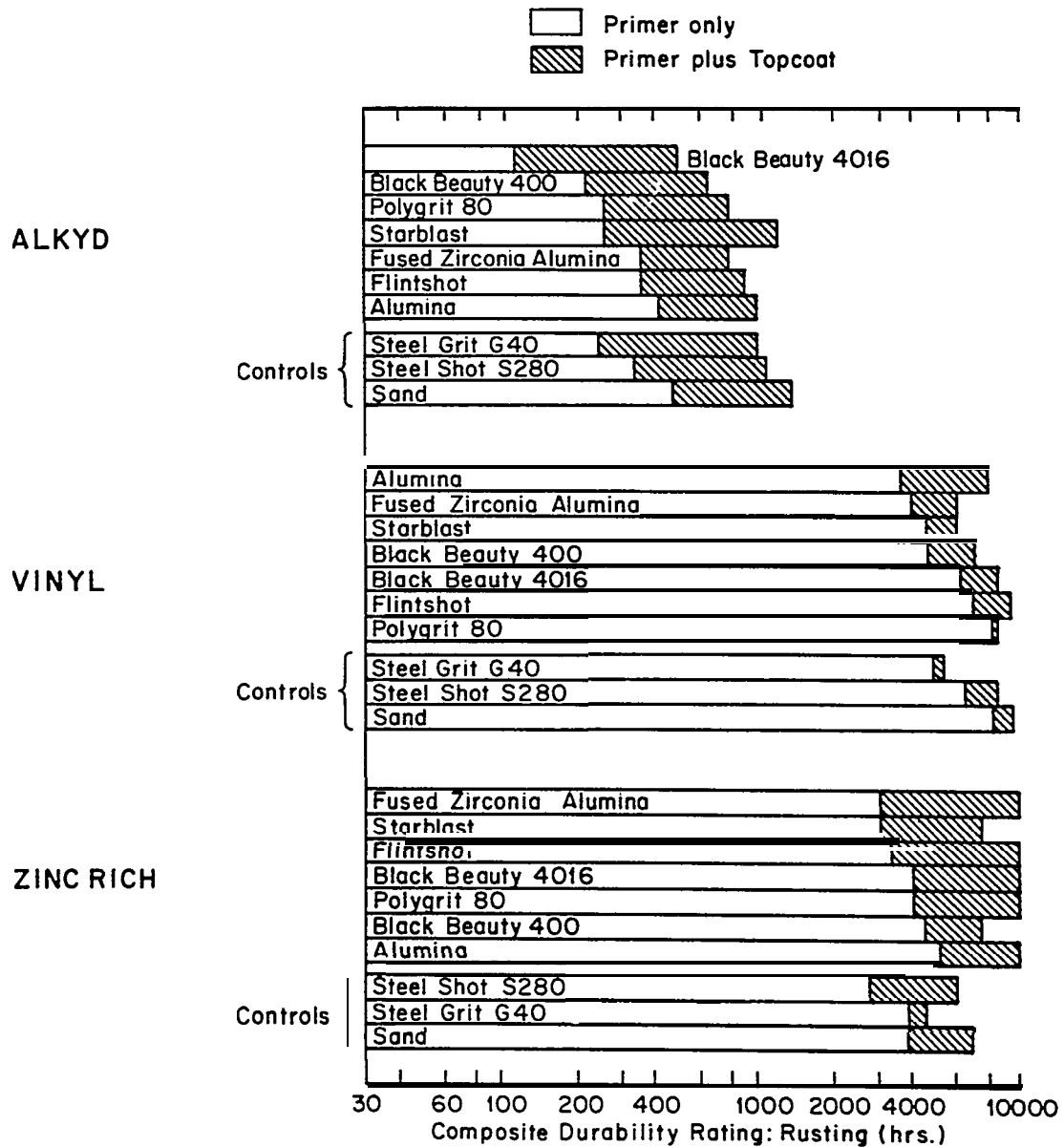


FIGURE C.8: Effect of Degree of Cleaning for Surface Blast Cleaned with Metallic Abrasives  
Salt Fog Exposure



Results of other SSPC tests, both atmospheric and in the salt fog cabinet, does not show large differences in performance as the degree of cleaning was increased from commercial (SSPCSP 6) to near-white (SSPC-SP 10) to overblast. For some coatings in some environments, in fact, the commercial or near-white grade appeared to be the optimum one. Scanning electron microscopy indicates that this paradox may be due to the existence of two competing mechanisms involving removal of mill scale and other contaminants versus working of the metal surface.

(4) Abrasive Size and Profile Height - As expected, abrasive size is the most critical variable in establishing the height of the anchor pattern profile. Certainly the velocity of the abrasive hitting the steel surface is also very significant. Figure C.9 shows the variation of profile for a range of steel shot and grit abrasives used under typical operating conditions in a centrifugal wheel type blasting cabinet.

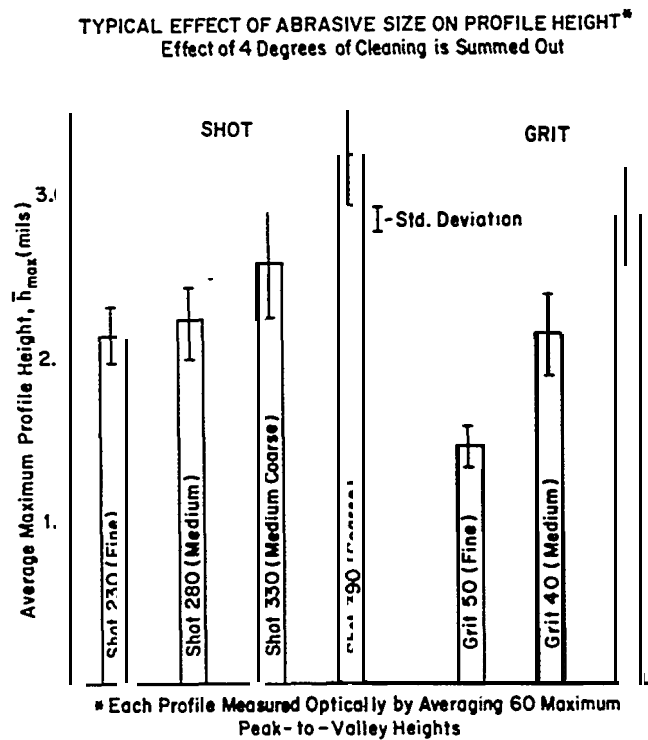


FIGURE C.9

SSPC tests, however, have shown that within the normal range of abrasives used in good painting practice, the resulting variations in profile have a relatively minor effect on the performance of typical generic coatings exposed in typical environments. Any adverse effects attributable to excessive profile, in these tests, were limited to performance of single coats of shop paints and were correctable by moderate increases in paint thickness. Therefore, based on these results, no need has been shown for imposing narrow profile limits beyond existing requirements (typified by the SSPC surface preparation specification's stipulation that no metallic abrasive larger than 16 mesh be permitted).

(5) Coating Thickness Over Varying Profiles - Coating thickness has been shown to be a much more important parameter than profile in determining paint performance. SSPC exposure tests have indicated the presence of a "critical film thickness" below which a primer will not protect the substrate steel even for a small period of time. (See Table IX)

Table IX  
CRITICAL FILM THICKNESS

CRITICAL FILM THICKNESS (Mils)					
Surface Preparation	Surface Profile	Salt Fog Alkyd	Salt Fog Vinyl	Mild Industrial Alkyd	Mild Industrial Vinyl
S230-SP5	2.2	0.7	0.9	0.5	0.8
S330-SP5	2.4	0.9	1.2	0.9	0.8
G80-SP5	2.0	1.2	0.8	0.5	0.8
G50-SP5	2.9	0.7	0.8	0.5	0.5
G14-SP5	5.0	1.7	1.8	1.0	1.1

This critical thickness is greater for coarse profiles than for finer ones, apparently due to a lower paint thickness over a few highest "peaks" out of a total of 30,000 to 100,000 peaks in every square inch. Studies have shown, at least in some environments, that a moderate increase in paint thickness can be used to compensate for excesses in profile height (or even for normal variations in degree of cleaning between commercial and white metal).